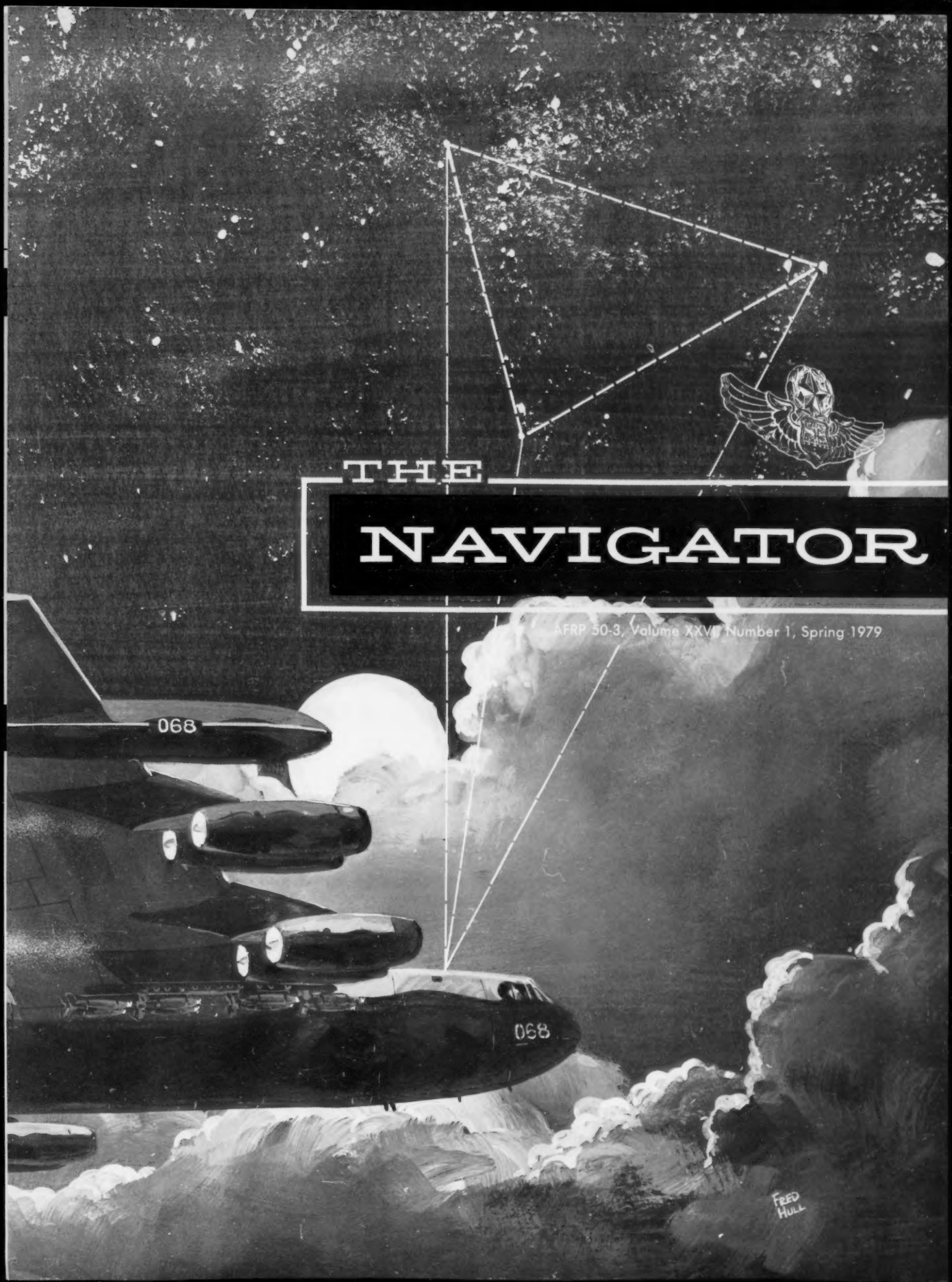

AFRP 50-3, Volume XXVI, Number 1, Spring 1979

NAVS OF NOTE

Colonel Clifford D. Cork is Deputy Director for Strategic Forces and Communications, Command and Control, and Intelligence at Headquarters USAF.

Colonel Cork was born in Colome, South Dakota. He entered the Air Force in 1952, received his commission as an aviation cadet, and graduated from navigator training in March 1955. Now a master navigator, Colonel Cork's flying experience spans 5500 hours in KB-29, KB-50, B-47, B-52, and UC-123K aircraft.

From March 1955 until June 1958, Colonel Cork served with the 429th Air Refueling Squadron at Langley AFB, Virginia. After training in the B-47 in September 1958, he was assigned to the 307th Bomb Wing at Lincoln AFB, Nebraska, until February 1965. Colonel Cork's aircrew experience culminated at a dozen years with his duty in B-52G aircraft at Beale AFB, California.

Moving from the cockpit to the staff of the Deputy Commander for Operations at Beale, Colonel Cork was then selected to command the 456th Avionics Maintenance Squadron in April 1968. He held this position until being transferred to Southeast Asia in 1969.

From December 1969 until December 1970, Colonel Cork was Commander, 56th Avionics Maintenance Squadron and Assistant Chief of Maintenance, 56th Special Operations Wing. In these capacities, he flew "Candlestick" missions in the UC-123K. Also, during his tour at Nakhon Phanom RTAFB, Thailand, he was project officer for the Pave Eagle II reconnaissance program.

The 5th Bomb Wing at Minot AFB, North Dakota, welcomed Colonel Cork from Southeast Asia in December 1970. Here he worked for two years as the unit's Maintenance Control Officer. Reassignment at the completion of this tour led the colonel to Offutt AFB, Nebraska, and work as the Assistant Deputy Commander for Maintenance in the 55th Strategic Reconnaissance Wing.

Colonel Cork became Deputy Commander for Maintenance for the 100th Strategic Reconnaissance Wing in 1972. He became Vice Commander of the F. E. Warren AFB's 90th Strategic Missile Wing in 1974 and held that post until 1976 when he assumed command of the 351st Strategic Missile Wing, Whiteman AFB, Missouri.

Colonel Cork reflects upon many interesting experiences over the years. The most harrowing was his low-level downward ejection from the seat of a B-47. Logging many hours in another stalwart of the United States' manned bomber force, Colonel Cork has witnessed many improvements in the B-52 navigational systems, including those facilitating today's low level techniques.

In 1967, Colonel Cork participated in an initial test of the Emergency Rocket Communication System (ERCS), while flying on a B-52 crew over the Pacific. Ironically, he later had operational jurisdiction over the ERCS network as commander of the 351 SMW. He also has been involved in the operational evolution of Remotely Piloted Vehicles. Tracing their development and operational deployment in Southeast Asia by the Strategic Air Command, Colonel Cork witnessed their contribution to the success of the Linebacker missions. He believes that RPVs, currently deployed by Tactical Air Command, will have continuing utility in the Air Force mission.

Commenting upon the dynamics he has seen in the ranks, Colonel Cork describes the average age of today's air and missile crews as "amazing" compared to his days on the crew force. He added that, "Today's younger personnel are the best qualified I have seen in my career."

When asked for his advice for young navigators, Colonel Cork stressed "aggressiveness in seeking increased responsibility, while doing the best possible job in today's environment of reduced levels of equipment, funds, and personnel. It is advantageous for navigators to know as much as possible about associated areas and systems."

The Space Shuttle Orbiter crew positions are commander, pilot, mission specialist and payload specialist. The commander and pilot fly the Orbiter. A mission specialist normally will be assigned as a spacecraft-proficient crew member who is also skilled in payload operations, and who can assist the payload specialist(s) to function effectively. We are happy to report that an Air Force navigator, Major Richard M. Mullane, is in training as a mission specialist.

A native of Albuquerque, New Mexico, Major Mullane graduated from the United States Military Academy in 1967. He completed 150 combat missions as an RF-4C weapon systems

operator while stationed at Tan Son Nhut AB, Vietnam, from January to November 1969, and served a subsequent four-year tour of duty at Royal Air Force Base, Alconbury, England.

Major Mullane next attended the Air Force Institute of Technology in 1975 and was awarded a Master of Science degree in Aeronautical Engineering. In July 1976, upon completing the USAF Test Pilot School's Flight Test Engineer Course at Edwards AFB, California, he was assigned as a flight test weapon systems operator, 3246th Test Wing, Eglin AFB, Florida.

In January 1978, Major Mullane was selected as an astronaut candidate by NASA and, in July, began a two-year training and evaluation program to qualify for subsequent assignment as a mission specialist on space shuttle flight crews. **Editor's Note: We hope Major Mullane's fighter background doesn't give him any trouble in the celestial navigation portion of his training. We are sure it won't, and look forward to reporting on our first navigator in space.**

FROM THE EDITOR

Our purpose is to disseminate technical and professional information of interest to navigators. Fortunately, we get constant feedback that helps in trying to meet our readers' needs. But our most important information comes from the reader survey conducted every other year under the provisions of AFR 5-1.

The survey asks three questions: Do you have any ideas for future stories? Are you satisfied with our format and content? And, do you think we accomplish the purpose of disseminating information?

We ask your cooperation in completing the self-addressed, postage-paid survey you'll find inserted in this issue. If the survey has already been used, won't you write us with your thoughts on those three questions?

One point we emphasize is that we depend on you for story ideas. What new equipment, tactics, techniques, and developments do you think other navigators should know about? In pursuing story ideas, we often find that the central actors in projects such as avionics testing, for example, don't have the time to write a magazine story. We appreciate that most important fact — the mission comes first. For that reason we ask you to send story ideas when you can't write a full story. Then we can use our resources to have the story written. The bottom line is that THE NAVIGATOR magazine can best serve by helping share the information that only you can provide.

Thank you for completing the survey — and for your ideas!

TO THE EDITOR

Dear Editor

Congratulations on your 25th Anniversary Issue; it is one all navigators can gain much from.

By now I'm sure you have reviewed the current Institute of Navigation Journal that is dedicated to GPS-NAVSTAR. May I suggest that you call it to the attention of your readers who will want to add it to their personal navigation library.

Leonard R. Sugarman
Colonel, USAF, Retired
Assistant to the Director
Resources Management
Physical Science Laboratory
New Mexico State University

Editor's Note: The following letters concern Captain Eickmeier's critique, in the Summer 1978 issue, of an article by Captain Patrick L. Campbell in the Summer 1977 issue. Captain Campbell had argued that selection of an assumed position and shooting sequence can induce errors in celestial work. Captain Eickmeier's critique was somewhat technical, but he summarized by claiming that complex schemes of correcting for shooting early are foolish when contrasted with the ease of the three LHA, 4-0-4 shooting schedule. Whatever the answer to that controversy, we think you'll find these letters interesting as the authors have moved on to another subject.

Dear Editor

Captain Eickmeier's letter in your Summer '78 issue is a point well taken — especially his criticism of complicated methods to combat the inaccuracy of shooting early.

It has never ceased to amaze me that we have always tried to teach students the easiest, fastest, best and most accurate way of plotting celestial information only to find that in a few short years the former

(Continued on page 31)

DEPARTMENT OF THE AIR FORCE

THE NAVIGATOR

AFRP 50-3, Volume XXVI, Number 1, Spring 1979

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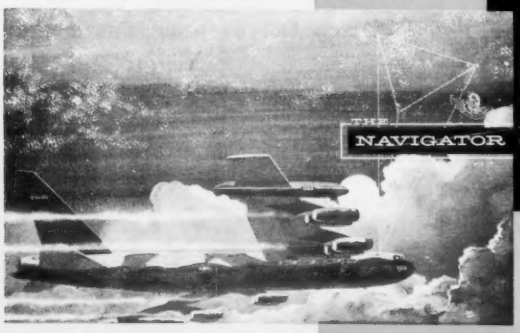

Our cover depicts that strategic stalwart--the B-52. Its crew might be able to use our new feature--Stargazer--on page 21. The second half of "Bomber Navigation" starts on page 25.

Please complete the reader survey inserted in this issue.

Distribution: One copy per two navigators.

determining the most probable position

Captain Kent EDIE
RAF School of Air Navigation
RAF Finningley

Captain Mike MARTINI
Department of Air Warfare
RAF Cranwell

When we were instructors at Mather we quickly learned one principle of navigation—"There are many ways to do the job." While serving as exchange officers with the Royal Air Force, we have learned that there are even more ways on this side of the Atlantic. One of the most fascinating differences we have observed and have tried to perform, with some success, is the RAF's method of establishing an MPP.

When a USAF navigator says MPP, you know he means the position resulting from a DR and a sun line. The C-plot formula covered in AFM 51-40 provides guidance for systematically establishing an MPP. It considers only the time run since the last position and the perpendicular distance between the DR position and the LOP. The formula is based on the fact that accuracy of celestial information is unaffected by time whereas the accuracy of the DR degrades with time. But let's look at the information C-plot does not cover. If we use a navigation aid that is consistently more accurate than celestial information, then use of the C-plot technique might be undesirable. What do we USAF navigators do when we have more than one LOP? We generally rely on our nav judgment and use one of three methods: TLAR (that looks about right), WAG (wild approximate guess), or SWAG (scientific wild approximate guess).

The RAF's method of establishing MPPs, on the other hand, is a compromise between statistical correctness and the speed and ease of a more practical method. We'll discuss the statistical concepts, then explain the necessary compromise by giving examples of constructing an MPP *The Royal Way*.

Have you ever obtained a perfect LOP, one that slices right down the middle of the exact aircraft position? "Very few, but most of them come close" is what you might say. In reality, every position we obtain is a probable position. Every LOP is subject to errors, the magnitude of which depends on various factors, such as the type of LOP, the operator's use of equipment, and the conditions at the time it is obtained. If you were to take a large number of observations from a nav aid in an aircraft frozen in position, you would find that the LOPs form a distribution about the true position of the aircraft. This distribution, depicted in Figure 1, is Gaussian, more commonly referred to

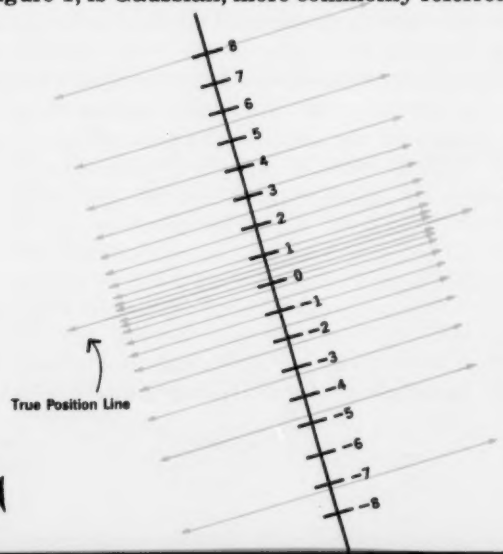

Figure 1
Statistical Distribution of Position Lines

as normal. The RAF uses certain parameters to describe the essential properties of this distribution. An explanation of these terms requires us to take a closer look at the distribution of LOPs.

If we were to divide the perpendicular displacement from the true LOP into equal intervals and tally the number of observations falling within each interval, we could plot what is known as a histogram (Figure 2). The number of

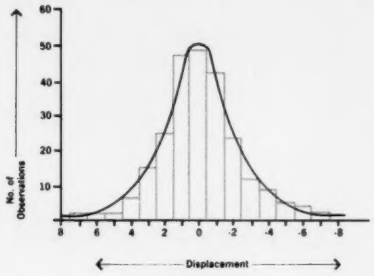

Figure 2 **Histogram**

observations in each interval is plotted along the vertical axis and the displacement intervals along the horizontal axis. Most of the LOPs will be near the true LOP, while a few will be further away. There always will be a few gross LOPs. The histogram can be approximated by the curve in Figure 3. Statistical sampling theory and

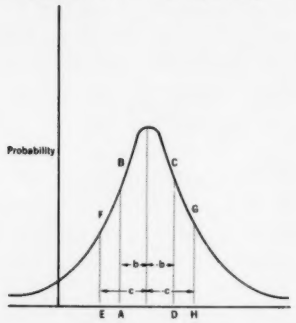

Figure 3 **Probablilty Curve**

experience show the curve to be normal, with the characteristic symmetrical bell shape. Since the area beneath this curve is the total number of observations, then the number of observations falling between two intervals, expressed as a percentage of the total, is the probability of an LOP falling within the two intervals. For example, we can say that 50% of the LOPs will lie within +b and -b, normally given in nautical miles, of the true position, as represented by the area ABCD, or 76% of the LOPs will lie within +c and -c of the true position, as represented by the area EFGH. The principle behind the RAF method of constructing MPPs uses the inverse of these statements. By analyzing many LOPs of the same type obtained in the past, it is possible to predict the interval or band that the LOP will lie on 50% or 76% of the occasions.

The displacement interval from the true position where 50% or 76% of the LOPS will fall from a particular navigation aid is called a half-width band of error. Navigation aids have different accuracies and, consequently, different bands of error. The RAF has done extensive flight trials on the accuracy of different navigation aids. Table 1 contains a list of the half-width

Type of Position Line	Band of Error (Half-widths)	
	50%	76%
Transit Bearings	0·5°	0·9
Visual Bearings:		
a. Astro Compass	2·5°	4·5°
b. Peri-sextant	1·5°	2·5°
Astro:		
a. Aircraft speed 120–220 k	5 nm	9 nm
b. Aircraft speed 0·65 to 0·86M	8 nm	14 nm
TACAN:		
a. Bearing	2°	3·5°
b. Range	0·2 nm	0·5 nm
VOR	3°	5°
Automatic Loop Bearings	1·5°	2·5°
Consol:		
a. Day—all ranges	1 character	2 characters
b. Night:		
(1) Less than 150 nm	1 character	2 characters
(2) 150–250 nm	3 characters	5 characters
(3) 250–450 nm	6 characters	11 characters
(4) 450–550 nm	3 characters	5 characters
(5) over 550 nm	1 character	2 characters
Loran A:		
a. Ground wave	6 micro-seconds	11 micro-seconds
b. Sky wave	16 micro-seconds	28 micro-seconds
Loran C:*		
a. Ground wave (< 1100 nms from transmitter)	0·5 micro-seconds	1 micro-seconds
b. Sky wave (> 1100 nm from transmitter)	3 micro-seconds	5·5 micro-seconds
Cloud Warning Radars:		
a. Range	2 nm	3 nm
b. Bearing	3°	5°
Gee	0·016 Gee units	0·030 Gee units
Rebecca Mk 4	3% of range	5% of range

*Beyond 700 nm from transmitter Loran C can be subject to a 10 micro-second ambiguity whose probability increases with range.

TABLE 1 BANDS OF ERROR

bands of error for some of the more commonly used aids. It is an extract from Air Publication (AP) 3456G, the RAF counterpart of AFM 51-40.

The use of this table is straightforward. Let us assume an RAF navigator plots a VOR LOP. By referring to this table, he knows that if he were to add and subtract 3 degrees from the VOR reading and plot this information, he would then have a 50% chance of the true aircraft position being within this band. Or, he may wish to apply 5 degrees to his VOR reading to determine the 76% band of error.

The detailed reasons for using 50% and 76% bands of error is beyond the scope of this article; however, they may be summarized by one word: practicality. To be 90% confident that our band of error will contain the aircraft position, the size of the band would need to be comparatively large. The impracticality of working at such high levels of confidence will become apparent when we ask you to construct MPPs.

This brief look at the statistics behind LOPs is only half the story since we have not considered

the DR position. We know a DR position is not perfect, an area of uncertainty exists around it. The RAF has statistically analyzed DR positions, especially Doppler aided computer positions, to derive the size and shape of this area of uncertainty. For an example, we will use a Doppler aided computer position, but the discussion can be equally applied to other types of DR positions.

Let us assume that our DR position is accurate along track but has errors in across track. Analyzing many tracks of equal distance would give an arc of DR positions, as on the circumference of a circle whose radius would be equal to the length of the tracks (Figure 4). The

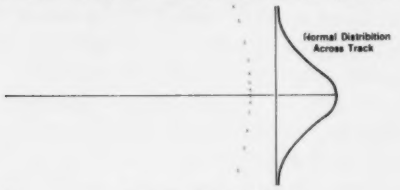

Figure 4 Across Track Errors

error in the positions should be distributed normally along the arc. If errors are now introduced in the along track dimension, then the arc of the circle will develop into a curved ellipse (Figure 5). Since Doppler groundspeed is usually

Figure 5 Curved Ellipse

more accurate than heading, across track errors are greater than along track errors. The actual shape of the distribution will depend on the accuracy of the system's inputs. Its size, on the other hand, depends on the level of confidence at which the navigator may choose to operate and the time since the last position. The 50% area of uncertainty is used, giving the navigator an even chance of this curved ellipse containing the aircraft position.

Theory shows the area of uncertainty to be a curved ellipse centered about the DR position. Plotting LORAN LOPs is difficult, but can you imagine the difficulties in plotting a curved ellipse? Indeed, a practical employment of the above theory becomes even more difficult when the aircraft alters. If the aircraft alters 90 degrees between positions, then the previous cross track error becomes an along track error. After a number of alters, the area of uncertainty would be closer to a circle than an ellipse. Consequently, there is plenty of room for compromise and interpretation.

The RAF has not standardized the shape of the area of DR uncertainty. Such standardization would incorrectly assume the quality of inputs to the various ground position indicators to be the same. Instead, the particular shape used by a RAF navigator is dictated by command and local directives. Navigation Refresher Course students at RAF Finningley use a circle centered about the DR to represent the 50% area of DR uncertainty. The radius of the circle depends on the type of DR position. The DR uncertainty around an airplot DR has a radius of 8 nm/hour for TAS of less than 250 knots and 20nm/hour for TAS of 250 knots and above. The radius for a Doppler/computer position is 6 nm/hour.

We have discussed the 50% and 76% bands of error for LOPs and the 50% area of DR uncertainty. Let's see how this is put into practice constructing several types of MPPs.

Single Position Line MPP

Figure 6 shows the construction of a single position line MPP. The half width of the 50% band of error is used in this construction.

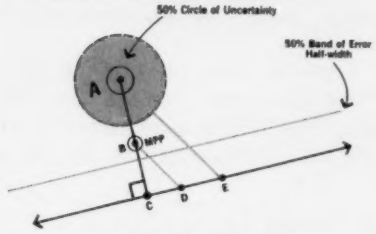

Figure 6 Single Position Line MPP

1. Construct a perpendicular from the DR to the LOP (AC).
2. Along the LOP mark off a length equal to the half-width of the 50% band of error (CD) for the particular nav aid.
3. From D, mark off the radius of the DR's 50% circle of uncertainty (DE), which is proportional to the elapsed time since the last position.
4. Join AE and parallel this line through D to give the position B, the MPP.

You should remember that this method is a compromise between practicality and precise accuracy. That is because we combine linear and radial errors which, strictly speaking, we should not do. Also, we ignore systematic errors and assume that the distribution of LOPs from a particular nav aid is centered about the aircraft position. But few practical benefits would be gained by trying to correct these assumptions.

Two Position Line MPP

Figure 7 shows the statistical distribution of two LOPs about aircraft position. Examining a

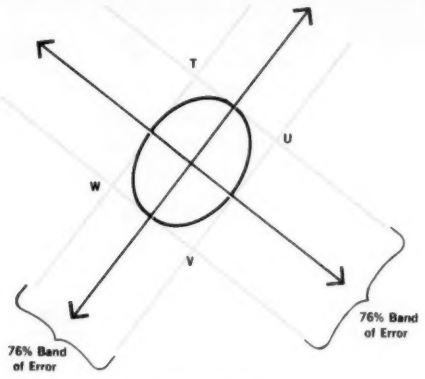

Figure 7 50% Ellipse

fix produced by two such distributions intersecting each other results in an elliptical distribution about the true position. Again, use of such a creature is difficult, and a compromise between theory and practicality is necessary. A parallelogram formed by the 76% bands of error is used instead of the ellipse. The probability of the true position lying somewhere in the resulting parallelogram TUVW is 58% (76% x 76%). Only an insignificant error is encountered by this shortcut.

8 Figure 8 shows the construction using half-width 76% bands of error and the 50% DR area of uncertainty. The MPP is assumed to be on the line joining the LOP intersection to the DR position.

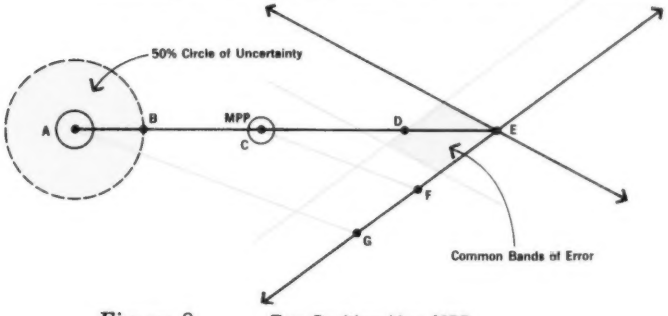

Figure 8 Two Position Line MPP

1. From A, draw a line to intersection E.
2. From E, construct EF equal to the portion of line AE contained within the common bands of errors (ED).
3. From F, construct FG equal to the radius of the circle of uncertainty (AB).
4. Join G to A and parallel this line through F. This determines the MPP along AE.

Three Position Line MPP

Yes, there is such a procedure, but the construction can be complex and explaining the various methods used would require a separate article. The rule-of-thumb method of constructing a three-position line MPP given in AP 3456G is as follows:

1. Mark the center of the triangle.
2. Construct the 50% area of DR uncertainty.
3. The center of the triangle is the MPP if it is within the area of DR uncertainty; otherwise, the MPP is the mid-point of the portion of the line adjoining the DR and the center of the triangle.

Only a few navigators use these MPP procedures described, others use variations of these, and the remainder are not required to use an MPP procedure at all. Indeed, the AP 3456G recommends constructing MPPs only when the position lines used to obtain a fix are of doubtful accuracy. Yet, student navigators at RAF Finningley must use MPP procedures.

The answer to this apparent paradox reveals the principal merit of using MPP procedures. The nav receives a set of procedures that makes use of the relative order of merit and predictable errors of the various navigation aids and computers. This order of merit can be helpful in selecting the best available aids and improving nav judgment.

We recommend you try your hand at plotting the examples. At first, you may be slow and have difficulty in plotting the various lines. After some practice, however, you will find the process quite easy and you will be able to construct MPPs *The Royal Way*.

For those purists who would like more information, write us at USAF/RAF Exchange Program, APO NY 09238.

A graduate of Capital University in Ohio, Capt Edie obtained his master's degree from the University of Southern California. After UNT, he served a SEA tour in the F-4, followed by assignment to Mather AFB in 1974. Capt Edie was a UNT instructor and a member of the ITS staff until 1977 when he entered the Exchange Program. He currently serves on the staff of the RAF School of Air Navigation, RAF Finningley.

Captain Martini graduated from the University of California at Los Angeles with a BA in mathematics. He served two SEA tours in the B-52 and was a POW from Dec 72 to Apr 73. Assigned to Mather AFB, he served as a UNT instructor until 1976 when he joined the Exchange Program. Capt Martini presently is on the staff of the Department of Air Warfare at RAF Cranwell serving as a Flight Trials Instructor and Acting Squadron Leader Guidance.

Statistical Filtering

Mr James J. Hairston
Boeing Aerospace Corporation
Houston, TX

The use of more accurate and complex systems such as INS is a current trend in aircraft navigation. In most cases, some type of statistical filtering is used to align the INS. Such a statistical analysis compares input velocities from a Doppler radar, or some other wind or positioning source, with the velocities developed by the INS. The difference value, generated by this comparison, is used to align the INS.

But why do we need such a process? Because, if we aligned an INS, using as an example, Doppler as a velocity source and manual positions inserted by a navigator, the level of accuracy would depend on the accuracy of the input data and could never exceed that accuracy level without a statistical filtering process.

Our objective is to determine a degree of accuracy for the Doppler and the INS and the amount of Doppler inputs we will accept. If there is an error in the INS, it will be either in azimuth or tilt—if such an error exists INS velocities will not agree with the Doppler. Since a position error is also caused by either tilt or azimuth error, we can use them to align the INS.

To accomplish this, first we can develop a correlation coefficient — a measure of how well the data fits the best fit curve. If we plot data such as in Figure 1, with INS in the vertical and Doppler on the horizontal, we can establish a best fit curve for the data and calculate a correlation coefficient. Each small dot represents a sample of Doppler velocity compared with INS velocities. Each large dot represents a comparison of INS and NAV positions. The velocity samples are taken each 6 seconds, and the entire sample is for the last 90 minutes. As new data is accepted after INS alignment, old data is dropped from the comparison. Each position update is better than a comparison of velocities so it is weighted and regarded as equal to 20 minutes of velocity inputs. Position inputs are inherently better since they represent an accumulation of velocities. The correlation coefficient not only measures how well the data fits the best fit curve, but also how well the Doppler velocities and NAV positions agree with the INS. If the correlation was "1," then all data points would fall exactly on the best fit curve, and the INS could be regarded as 100% correct. If the correlation was ".5," then the INS is 50% correct, etc.

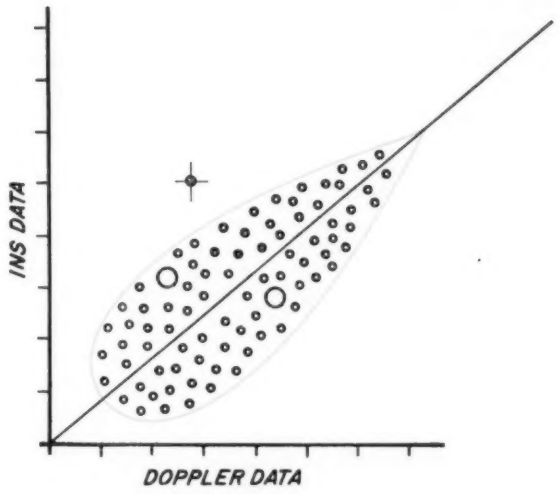

Figure 1

After initially starting the system, the correlation will be very low, and we will rely heavily on external sources to align the INS. As time goes on and more data is obtained, the correlation increases. This increasing correlation means that the INS comes to agree more and more with the external updates. As this happens, we accept less inputs from the external sources because the INS is becoming more accurate.

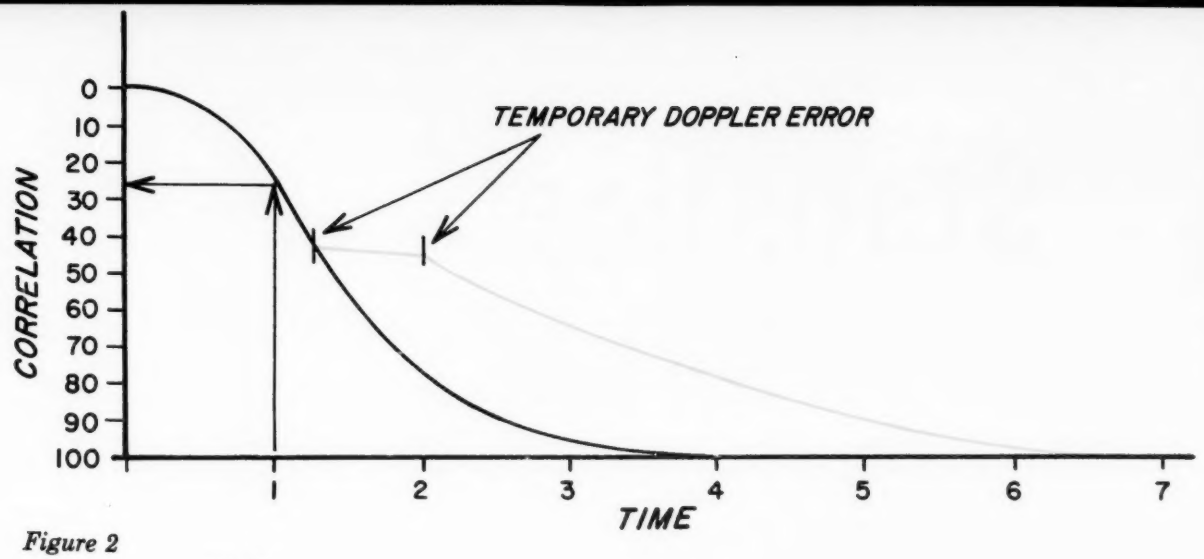

Figure 2

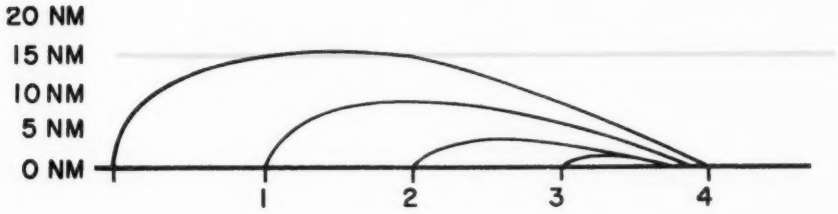

Figure 3

In Figure 2 the solid line is a plot of correlation coefficients versus mission time. The correlation starts at zero and approaches 100% as time increases. When the correlation is nearly 100%, the error is insignificant and the INS no longer relies on any external source for alignment. At that time, the INS regards itself as 100% correct and cannot be updated. This is called "steady state." If, however, the Doppler or external source of data erred (as shown by the dotted line from the 1¼ hour to 2 hour period), the time to steady state would be considerably longer. This plot of data for a given time determines how much external data to use. For example, at the one hour point, 75% of the input is used because the INS is 25% correct.

The next task is determining the acceptable input data. In Figure 1, the data point marked "⊕" is obviously outside the envelope of acceptable data and, therefore, unacceptable. This type analysis could be performed for both position and velocity inputs, but is usually limited to velocity inputs. A more sophisticated procedure is normally used for the position inputs.

The correlation coefficient is used to establish an acceptable range of error based on time between updates. A family of curves in Figure 3 shows the acceptable value of position error plotted against time. The figure indicates a new fix was obtained once an hour and, thus, a new cone of acceptance was established at each fix.

The shape of the cone is based on the maximum allowable error established (as 15 nm in Figure 3) and the correlation coefficient from Figure 2. The correlation coefficient determines the slope of the curve. For example, the initial slope at the one hour point would be 75.5 degrees from the horizontal. (This angle is equal to the inverse cosine of the correlation coefficient.)

This process provides a reasonability test. The INS tests a new position input and if the error is excessive, the position is rejected. If acceptable, it is used to update the INS, but only by the current percent of acceptance, and is entered as a data point in the correlation computation. With this new method we cannot only align the INS but also make it more accurate than the input data used.

Mr Hairston, a graduate of Jacksonville University, obtained his master's degree in System Safety Engineering from the University of Southern California in 1977. He served as an NBT instructor at Mather AFB prior to his Air Force retirement in 1978. Presently employed by Boeing Aerospace Corp., Houston, Mr Hairston is a safety engineer in the Nuclear Safety Analysis Program.

reverse DR

Captain Walter P. WEST
Arnold Engineering
Development Center
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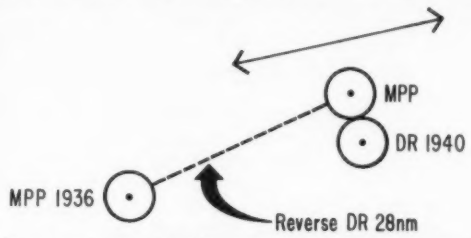
With air traffic increasing, radar vectors from Air Route Traffic Control Centers (ARTCC) are becoming more and more common. These vectors can come at the most inopportune times and create a problem for navigators during celestial navigation.

A heading change for any reason, be it for weather or ARTCC reasons, can pose problems for navigators if they are not aware of the reverse DR method. This technique is easy to figure and simple to apply. The celestial observations for the most probable position (MPP) and celestial fix normally are taken prior to the fix time. The crucial time for navigators is during these observations. For the MPP, this is usually 9, 6 and 3 minutes early; and for the celestial fix, 12, 8 and 4 minutes early. These observations are then used to predict the aircraft's position at a selected time in the future, provided the aircraft's heading is not changed during or after the observations. But if the aircraft is altered, the MPP or celestial fix will be in error for fix time.

However, if one or all of the celestial observations have been taken prior to the required or directed heading change, the resolved MPP or fix can be used to update your position at the time the aircraft's heading was changed. The procedure is to resolve the MPP or fix with the information that you were able to obtain prior to the unscheduled alter heading. A DR position is then computed for the amount of time between the unscheduled heading change and the selected fix time. As an example, say that you have precomped for a position at 1940Z. Your last



position was at 1900Z. The shot times for the celestial observation were at 1931Z, 1934Z and 1937Z. At 1936Z, at the beginning of your third observation, you receive an alter heading from ARTCC. Prior to 1936Z you had been on a true course of 065 degrees with a groundspeed of 420 knots. If this track had been maintained after 1936Z, your position at 1940Z would have been the resolved MPP or celestial fix. The DR for the time difference between 1936Z and 1940Z is 28 nautical miles. From the resolved position at 1940Z this 28 nautical mile DR is plotted on the reverse track of 065 degrees, or 245 degrees. This position at 1936Z is a fix or MPP for the time ARTCC gave you the alter heading. A sample log is illustrated in Figure 1.

TIME	FIX SYM.	PRESENT POSITION	T.C. OR G.C.	WIND	DC	T.H. OR G.H.	VAR OR I PREC.	M.H. OR AGH	TAS	AIR DIST.	DIST. TIME	GS	NEXT POINT DIST.	NEXT POINT TIME	ETA
1940			065		+2	067	-09	058	400		140 20	420			
1940			065		+2	067	-09	058	400			420			
1936		Plot reciprocal 245 degrees	065		+2	067	-09	058	400		28 04	420			

Figure 1

This reverse DR method can save valuable training time. So, the next time you are accomplishing a celestial navigation leg and an unscheduled alter heading is required during that crucial time, try this technique. It works!

Capt West graduated from the University of Kansas in 1971 with a BS degree in Aeronautical Engineering. After UNT in 1972, he attended CCTS at Castle AFB. He was then assigned to a KC-135 combat crew at Altus AFB and subsequently upgraded to Stan/Eval Instructor Navigator in 1978. Capt West was selected for Rated Supplement Duty at Arnold Engineering Development Center, Tullahoma, Tennessee, and currently serves as Aeronautical Engineer, Propulsion Wind Tunnel Facility.

The Plastic Overlay Trick– Alternate Rendezvous Method

Major John M. RAVENEL
Alaskan TTF Operations
Eielson AFB, AK

We in the KC-135 are constantly in search of new and different methods to effectively rendezvous with any aircraft capable of refueling in flight. One such method is the TACAN differential, only with a slight twist. Often the TACAN station is not aligned with the air refueling track. In such a case, the plastic overlay can be used to quickly determine the receiver's position relative to the tanker's.

The plastic overlay is drawn with ten nautical mile concentric circles surrounding ten degree radial bearings spoking from the center (Figure 1). It is drawn to a scale of 1 to 2 million for use with a JNC chart. Align the 360 degree radial to magnetic north of the TACAN station being used, and place the center of the overlay directly over the TACAN station. Now you are ready for instantaneous plotting of two aircraft positions. Make sure that both aircraft are tuned to the same TACAN station. From there, simply figure separation by using the range scale on the left of the overlay.

Figure 1

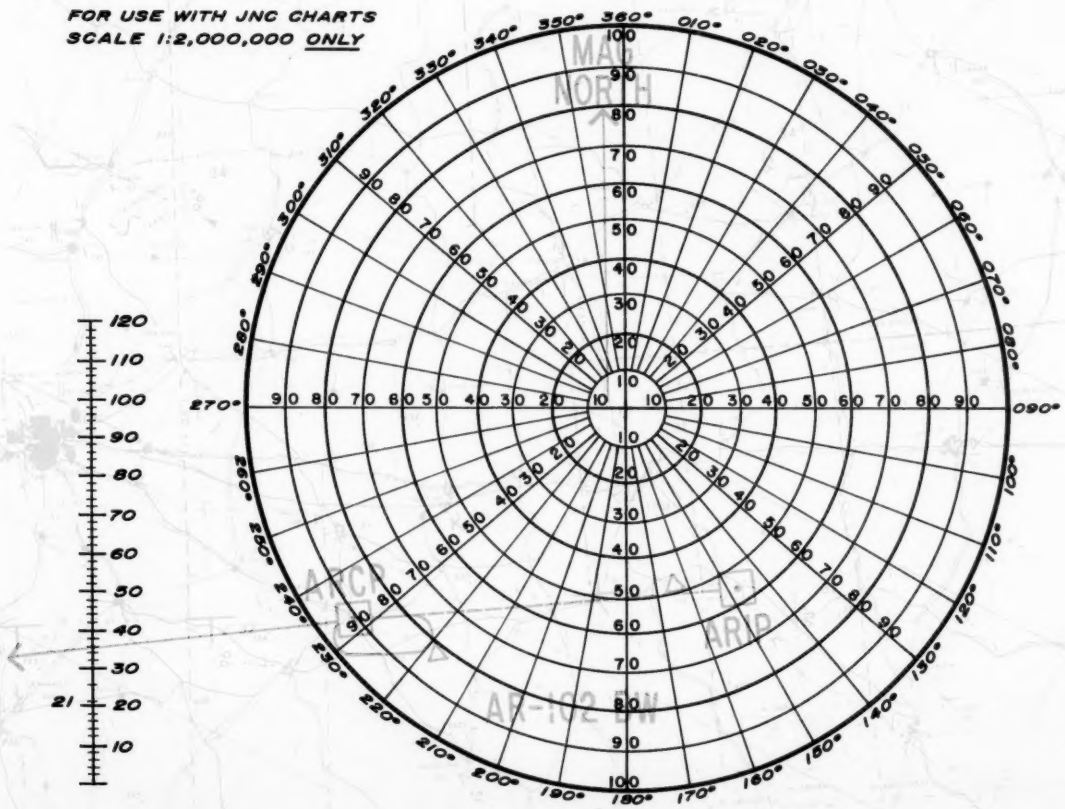


Figure 2 **ALTERNATE RENDEZVOUS TIMING CHART**

TAS / RNG	680	700	720	740	760	780	800	820	840	860	880	900
100	7:04	6:52	6:42	6:30	6:20	6:09	6:01	5:52	5:44	5:36	5:27	5:22
90	6:12	5:59	5:48	5:39	5:32	5:24	5:14	5:06	4:59	4:52	4:47	4:39
80	5:21	5:09	5:00	4:52	4:46	4:39	4:31	4:25	4:19	4:12	4:07	4:00
70	4:25	4:18	4:11	4:04	3:58	3:51	3:46	3:41	3:35	3:30	3:25	3:21
65							3:23					
60	3:31	3:25	3:20	3:14	3:09	3:04	3:00	2:55	2:51	2:47	2:43	2:40
50	2:39	2:33	2:29	2:25	2:21	2:18	2:14	2:11	2:08	2:05	2:02	1:59
40	1:44	1:41	1:38	1:36	1:33	1:31	1:29	1:26	1:24	1:22	1:20	1:19
30	:52	:50	:49	:48	:47	:45	:44	:43	:42	:41	:40	:39
25	:22	:21	:21	:20	:20	:19	:19	:18	:18	:17	:17	:17

TIME TO RUN FROM SLANT RANGE SHOWN TO 21 NM TURN POINT, USE COMBINED TAS OF TANKER AND RECEIVER, FOR OTHER THAN 21 NM TURN RANGE USE APPROPRIATE ADJUSTMENT.

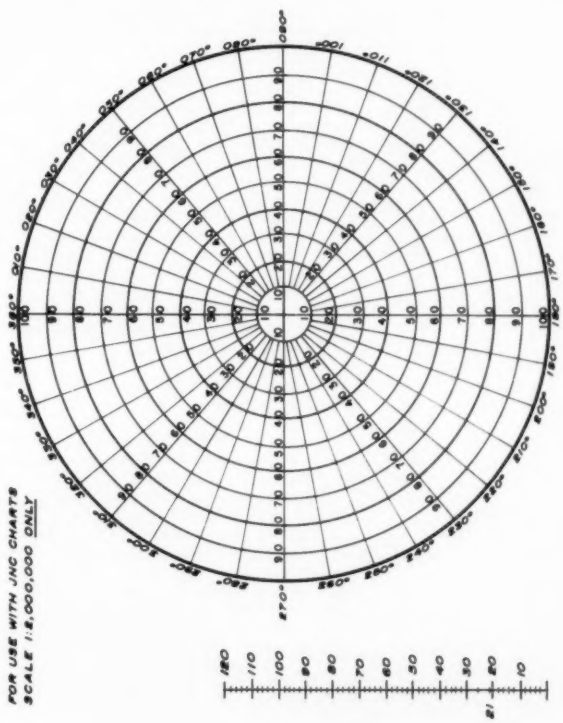
Combine this method with the alternate rendezvous timing chart (Figure 2), based on combined true airspeeds, and you have a fairly accurate backup method for joining up with another aircraft. Note that the timing chart is based on the distance to travel even though you enter with slant range.

As an example, suppose you are attempting to rendezvous with fighters on air refueling track 102BW. Since the Air Refueling Control Point (ARCP) and the Air Refueling Initial Point (ARIP) are defined off the Shreveport Vortac, Shreveport will be used for the rendezvous. From the receiver, obtain TAS for rendezvous, and radial and DME from Shreveport. Start your stopwatch and plot the position, e.g., SHV 160/50 and yours SHV 215/80. Enter the timing chart with the measured range, 65 nautical miles, and the combined TAS, let's say 800 knots. Through interpolation, the time to run for a 21 nautical mile turn range is 3 minutes and 23 seconds.

Remember, the timing chart is just a back-up method should the radar not lock on or the TACAN break lock during the rendezvous. It is always better to turn at a known distance, if available. Experiment on your own—that's how I came up with this method. Maybe you can improve it!

Maj Ravenel earned his commission and navigator wings through the aviation cadet program in 1964. He was then assigned to Loring AFB where he spent six years in the KC-135. In 1970, he transferred to Castle AFB as a CCTS instructor and later to the Stan/Eval Division. Maj Ravenel was reassigned to Barksdale AFB in 1975 and subsequently served as Assistant Chief, Training Division, 2d Bomb Wg. Currently he is assigned to the Alaskan Tanker Task Force Operations at Eielson AFB.

Editor's Note: The overlay should be enlarged and reproduced on transparent plastic. For use with JNC charts, scale 1:2,000,000, enlarge the overlay so that the diameter is approximately 7¼ inches.



THE NEW CONCEPT IN UNT

Lieutenant Colonel Jack G. WILSON
451 FTS/CC
Mather AFB, CA

Do all navigators perform duties similar enough to justify the same undergraduate training? Would tailored courses designed to produce navigator specialists at the undergraduate level jeopardize the utility and effectiveness of a "worldwide qualified" force? What effect would a navigator tailored training concept have on UNT? These questions and many more have been asked at all levels of the Air Force as the idea of a specialized training system has gained momentum. This article will attempt to explore the background and rationale for early specialized training and its impact on UNT.

NAVIGATOR CLASSIFICATION

The 15XX AFSC includes four groups of navigators performing highly specialized duties with varying commonalities.

Airlift and tanker navigators seem to best fit the traditional role. Even though their equipment varies from older Doppler equipped KC-135s and C-130s to the newer inertial equipped C-5s and C-141s, basic positioning aids and back-up system requirements are very similar. Celestial, LORAN, radar, and dead reckoning remain mainstays in the global capabilities of these aircraft.

B-52 and FB-111 radar navigators share some of these more traditional skills in addition to weapons system operation.

The F-4 and F-111 WSO, on the other hand, forego the more common skills and concentrate on radar navigation and weapons delivery with a knowledge of high speed visual navigation. To complicate matters, knowledge of the aircraft systems and performance characteristics becomes essential when the WSO doubles as a copilot.

Though the EWO finds himself in aircraft comparable to those of navigator bombardiers and WSOs, similarities in functions are few. In spite of training in radar, celestial, gyro steering, and overwater navigation, duty requirements in aircraft like the B-52 and Wild Weasel involve few navigational duties as such. As an electronic countermeasure equipment operator, he does not concern himself with navigation duties aside from a basic knowledge of airmanship and dead reckoning. The EWO's duties in the "two-seater" bear some similarities to those of the WSO. Obviously, all navigators have some thread of similarity, but there are costly training skills unused and lost over the years.

SPECIALIZATION CANDIDATES

Navigation becomes increasingly important as we deliver critical payloads over long distances under severe time constraints in any weather conditions. Add the potential of a hostile environment and the navigator becomes responsible for additional functions such as weapon system and electronic countermeasure equipment operation. Aircraft designed for specific missions have further complicated manning requirements necessitating different advanced qualifications of navigators, many utilizing skills taught outside UNT. The development of improved navigational equipment and requirements exceeded the "nuts and bolts" philosophy that dictated course content within UNT for so long. Equipment and knowledge in newer systems lagged behind weapon system developments and modifications, particularly during the Vietnam era when older aircraft assumed unique roles and the two-seat fighter reached its prime.

This specialization has produced WSOs, EWOs, navigator bombardiers, and airlift and tanker navigators. Although all have traditionally received identical basic navigator training, subsequent assignments and duty requirements have necessitated post-graduate specialized training by ATC and the operational commands. Two existing programs, NBT and EWOT, were developed due to demands for better trained graduates by gaining commands.

TAC's academic and flying programs compensated for the difficulty in acquiring, from any source, "back-seaters" with skills previously considered pilot duties. But the difficulty gave rise to the idea of an advanced school for WSOs similar to the NBT and EWOT programs.

TRAINING ADJUSTMENTS

The need for improved aircraft and simulators within UNT was satisfied in 1973 with the T-43

aircraft and, in 1974, with a much needed complementary simulator, the T45. To further enhance the program, T-37 aircraft were brought to Mather AFB to expose students to the two-man concept with emphasis on radio aids, penetration and departure procedures, and map reading. Further interest in modifications was prompted by the necessity for streamlining operations to reduce costs.

It was hypothesized that a specialized or tailored training system could create a navigator who would be more quickly and easily trained by using commands at reduced initial training costs. There might be a consolidated basic course with offshoots to tailored training programs for EWOs, WSOs, bombardiers, and airlift navigators to produce graduates who would then proceed to gaining commands for respective aircraft upgrading. Eliminating unnecessary global and gyro steering training for EWOs and WSOs, for an example, could reduce UNT training costs. Additional follow-on training courses at Mather AFB could be less costly than the current UNT program and could produce more readily adaptable navigators.

An abbreviated course could constitute the basic UNT program for all students. They would receive training in environmental subjects including military training, aviation physiology, weather, and life support. Students would then progress into basic navigational subjects including airmanship, navigation procedures, and navigation and aircraft systems.

Upon completion of UNT, all graduates would receive their wings and assignments. Every student would then enter a trailer course at Mather AFB. WSO and fighter-assigned EWOT students would enter a tactical navigation course conducted by Mather T-37 pilots and navigators. EWOT students assigned to B-52 aircraft would immediately enter EWOT while tactical EWOs would complete the tactical course before EWOT. The remaining NBT, tanker, and airlift assigned students would enter an advanced navigation course conducted by the UNT squadrons. The net difference—WSOs and EWOs would not receive overwater or gyro steering training and all students would receive more concentrated instruction in procedures more closely associated with their assigned aircraft.

The Tactical Navigation (TN) course would be designed to provide expanded instruction in low level navigation, weapons delivery, electronic warfare, tactical operations and maneuvers, and advanced aerodynamics. Approximately nine T-37 and five T-45 missions would give realistic introductory training in weapons delivery concepts plus instrument, formation, and visual low level navigation.

The Advanced Navigation (AN) course would encompass a combination of about four T-43 and five T-45 missions to provide the fundamentals of hyperbolic range control, international procedures, pressure differential, and gyro steering. Graduates would then proceed to respective gaining commands except navigator bombardiers who would enter NBT at Mather.

FACT OR FICTION

As we can see, the role of the Air Force navigator has undergone significant changes with the acquisition of increasingly complex weapon systems—a trend that will likely continue. Resultant specialization has produced navigational career fields bearing only basic similarities. The EWO and WSO have gained particular prominence as specialists performing duties quite different from the traditional navigator. Pressures to identify, train, and track specialists have gained considerable momentum when tied to improved training and potential money savings. A tailored training program at the earliest opportunity, the UNT level, would recognize these differences, improve training for specific systems, and eliminate unnecessary training without compromising USAF's policy of training worldwide qualified navigators.

If it all sounds farfetched, don't believe it! The first class of revised UNT students entered training in October and is scheduled to join the operational commands this summer!

Editor's Note: To keep you posted, we plan a future article on the progress of our first classes graduating under this important revision of UNT.

Lt Col Wilson, a graduate of Texas A&M University, completed UNT in 1969 after five years of nonrated service. As an RF-4 WSO, he served two tours in TAC and one in SEA. In 1973, he was assigned to Mather AFB and served as a UNT instructor navigator, flight commander, and Chief of Navigator Stan/Eval. He next completed Air Command and Staff College. Lt Col Wilson presently is Commander, 451 Fly Tng Sq, Mather AFB.

KC-10A

The KC-10A advanced tanker/cargo aircraft will "enhance the mobility, flexibility, and capability of the general purpose and airlift forces by aerial refueling, by carrying cargo, or both. Its mission is to provide increased mobility of US forces in contingency operations by: (1) refueling fighters and simultaneously carrying the fighters' support equipment and support personnel on overseas deployments, (2) refueling strategic airlifters, such as the C-5 and C-141, during overseas deployments and resupply missions, and (3) augmenting cargo carrying capability on a selected basis. In most instances, the KC-10 will perform these missions without forward basing and without depleting critical fuel supplies in the theater of operations. The Strategic Air Command has been designated as the operating command for the KC-10.

The KC-10A will be a derivative of the FAA certified McDonnell-Douglas DC-10-30CF. The aircraft will be modified for the tanker mission by installing fuel tanks (beneath the existing cargo floor), an aerial refueling boom, refueling operator's position, hose and drogue [illegible] refueling receptacle (receiver) [illegible] and provisions for carrying [illegible] KC-10A will also retain the [illegible] off-load versus [illegible] planner.

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Please complete this questionnaire and forward to THE NAVIGATOR magazine.

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4. Please indicate your response as to the quality and readability of the following articles and features:

	Excellent	Good	Fair	Poor
Nav of Note				
Editorial/Letters				
Navigrams				
Technical Articles				
Historical Articles				
Techniques				
Operational Experiences				

5. Please indicate your agreement with the following statements about THE NAVIGATOR:

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
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It has helped me to increase my professional knowledge outside my own field.					
It is a stimulating forum for new and diverse ideas.					
It is useful to me in my job.					

6. Do you have any story ideas or other suggestions for THE NAVIGATOR? _____

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NAME (Optional) & GRADE: _____ Primary Job Duty _____

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Reader Survey

CUT ALONG BROKEN LINE

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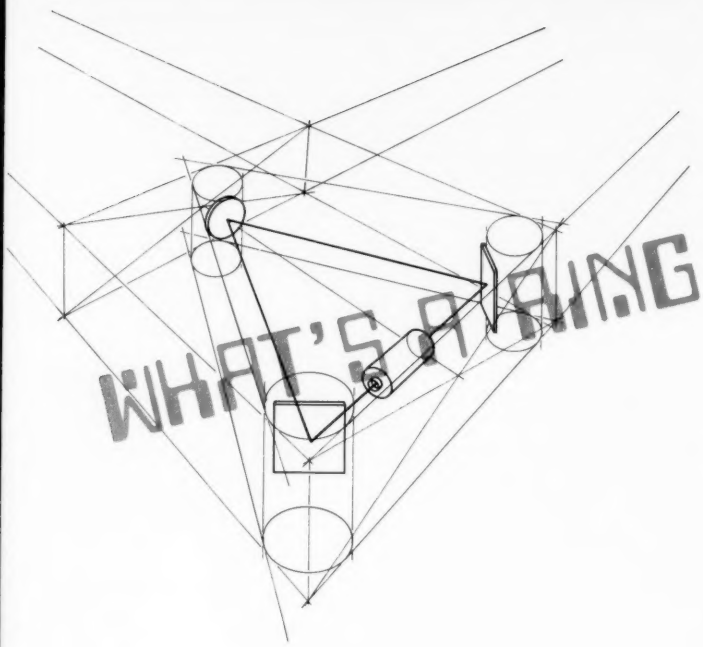
F. HULL



WHAT'S A RING LASER GYRO ?

Captain John T. BOECK, Jr
451 FTS/DO
Mather AFB, CA

Today's fictional stories about interstar travel, death rays, and UFOs make us take for granted quantum leaps in technology. But the revival of the Buck Rogers serials reminds me of just how far we have come. Admittedly, science affects every aspect of our lives but not many of the new advances have as many applications as the laser. The laser has been enlisted in a new way to improve the art of navigation. I would like to explain this development since soon you will be hearing more about the Ring Laser Gyro (RLG) and its navigational applications.

As long ago as the 1920s the concepts that are the foundation for the Ring Laser Gyro were known within the optical sciences. But the lack of a light source that would be highly directional and not prone to attenuation buried these concepts. In 1962, these ideas were unearthed as the newly invented laser's qualities became apparent. Researchers looked to this expanding field of optics as a tool in upgrading navigational and guidance systems.

The laser is a device which produces a coherent light emission of a single frequency which can be deflected, split and focused. Its extremely tight beam overcomes most of the diffusion difficulties of more common light sources. Both the coherence and monofrequency characteristics of the laser are the cornerstones of the laser's value.

Although mirrored surfaces, lenses, and electronic fields are used to direct and mold laser energy, the extensive arrays necessary to direct normal light are unnecessary. The laser emission's rate of diffusion is inconsequential — it retains its intensity and power over relatively great distances. Additionally, the thread-like cross-section of the beam contributes to an overall size reduction in the associated equipment.

The advantages of creating unique frequencies in electromagnetic wavelengths have long been used in electronics to make distance or velocity measurements using phase or frequency shifts detected under conditions induced by an object's location or velocity. This principle is utilized in such equipment as the Doppler radar which measures frequency changes due to relative motion between the signal source and reflector. Using lasers, the difference in frequencies is more readily and accurately detected and analyzed.

The RLG designs are many but generally they measure roughly six inches a side and are triangular. They include a triangular track with reflecting surfaces at two of the three corners. Either an externally generated laser beam is injected into the track or the track contains a gain medium (such as Neon or Argon) which is lased in the track. In either case, two beams are produced that race from the same point, in opposite directions. The beams are reflected at the corners toward the target at the third corner which is a sensor responsible for measuring the frequencies of the beams (see Figure 1).

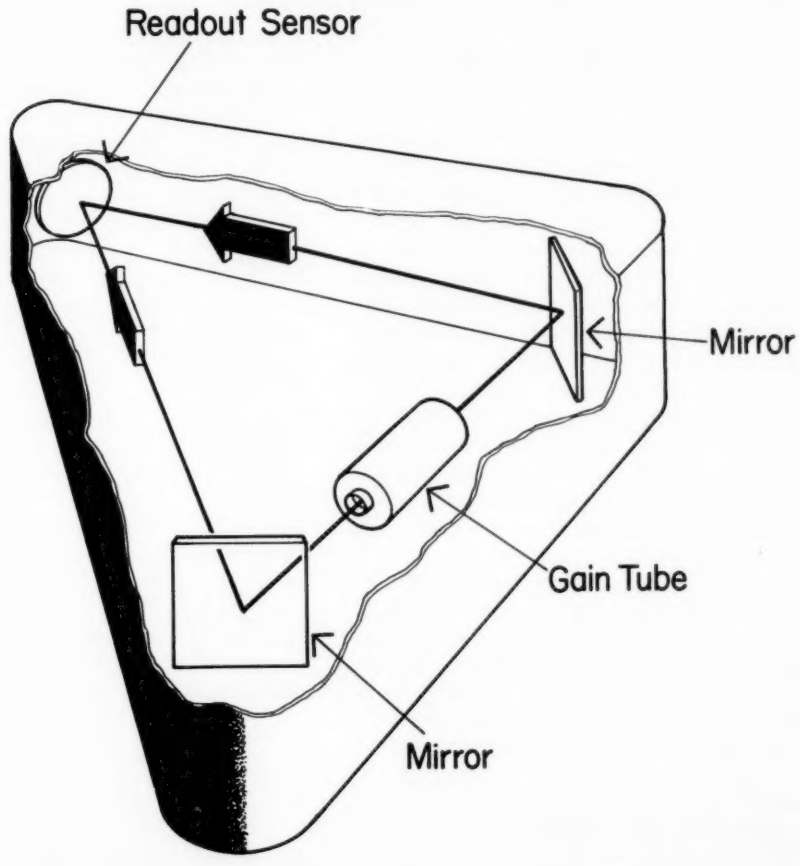
Assuming that the platform (perhaps an aircraft) on which the RLG is mounted is at rest, both beams will reach the receiving sensor at the same instant (having the same distance to cover). Their wavelengths are identical (remember the monofrequency characteristics of lasers) to the sensor at this point and the computer therefore assumes zero rotation of the laser's "track." Now, for ease of conception, let's isolate a segment (call it a pulse) of the beam to see how the frequency shift occurs when the platform moves in the laser's plane of sensitivity. Assume that the laser

produces 15 wavelengths in a certain time (this depends on the frequency produced by a particular element). Firing these pulses around a track of L, length, after T, time, the sensor detects that 15 wavelengths of both the clockwise (CW) and counter-clockwise (CCW) pulse arrived. Now imagine rotating the platform clockwise. Once released from a set point, if the platform is rotating, the CW pulse must travel L+Δ (Δ being the distance the platform moves in the time from release of the pulse until the pulse reaches the target). The opposite, (L-Δ) is true for the CCW pulse. Therefore, in the same time, perhaps 8 wavelengths of the CW pulse and 22 wavelengths of the CCW pulse are detected at the target. The computer uses this frequency shift to determine angular motion of the RLG. Being attached to a vehicle, any motion of the vehicle around the rotation axis of the laser track can be measured. This example is reduced to the basic concept for simplicity for, as one could imagine, the technology involved here is very complex but the example serves our purposes.

So far RLGs are plagued by a number of scientific and technological problems such as external electromagnetic fields, temperature expansion of wavepaths and something referred to as "lock-in." Major efforts are directed to solving these problems, particularly the last of these. For small angular rates of turn, interactions between the two counter-rotating laser beams create a tendency to nullify the frequency shifts. Alternatives thus far range from a simpler mechanical bias to complex electromagnetic techniques.

One of the mechanical bias techniques is to introduce a known movement to the platform. This raises the RLG sensitivity to a threshold at which point any further rotational input would register as angular motion but below which the "null" area causes a zero motion registration. Other efforts to mechanically reduce the "null" area concern movement of the reflecting surfaces which causes a predictable frequency shift which is recognized by the computer and discounted. In any case, care is being exercised to keep moving

Figure 1



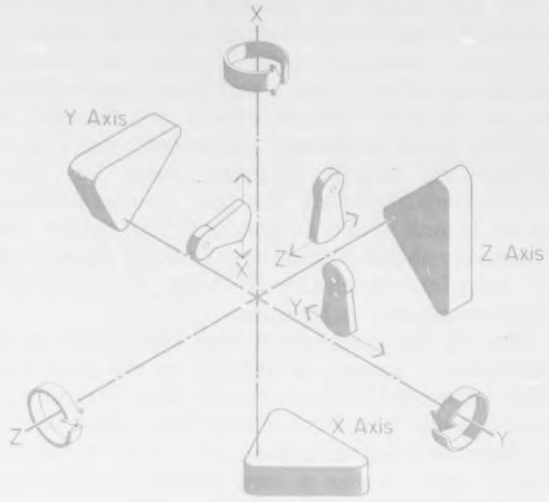


Figure 2

parts to a minimum to preserve the ruggedness, simplicity and low cost of the RLG.

Another promising solution to overcome the lock-in problem is the Differential Laser Gyro (DILAG). The DILAG involves lasing two isotopes of the same element in the same cavity thereby being able to generate and use opposing laser beams having a small but well known frequency difference to begin with. This mutual frequency difference eliminates the lock-in problem. Actually, as implemented, two separate laser gyros are made to use the same laser cavity; a rather complex arrangement to describe, but one having the ability to cancel out errors which appear in more conventional ring laser designs. As the state of the art on this and other design alternatives advances, the inherent errors are being reduced along with cost.

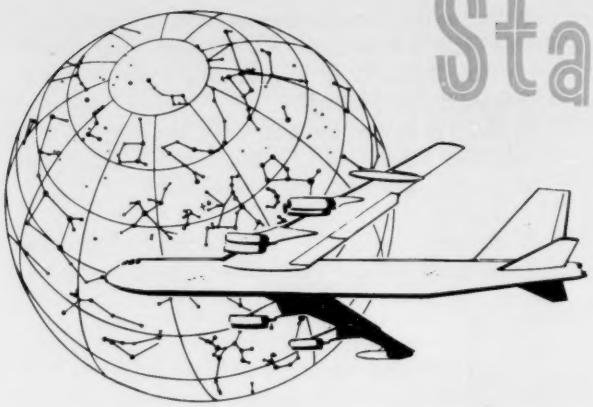
Despite the challenge presented by the mentioned errors, there are several Ring Laser Gyro designs suitable for inertial navigation systems (INS). In INS application, the angular rate of motion is measured in the RLG's plane of response and combined with accelerometers' outputs as an input to a computer which then provides the desired digital velocity, acceleration, and position outputs. This eliminates the complex and delicate gyro stabilized platform and its supporting equipment which are normally used. Of course, (and almost as important) by eliminating the platform stabilized by a mechanical gyro, we bid adieu to mechanical precession, and other undesirable considerations characteristic of inertial platforms.

Apart from the RLG, the components of the system are small and off the shelf. The typical system consists of an Inertial Navigation Unit (INU), Control Display Unit, Mode Selector Unit, power supply, and back-up battery, all similar to units in present systems. The difference is that the INU contains three RLGs, and accelerometers in place of the conventional gyro platform. Figure 2 illustrates the RLG-accelerometer setup for multiplane (e.g. up/down, north/south, east/west) implementation. This configuration allows sensing of the total dynamic motion of the platform that the INS is mounted on. Thus the RLG-configured inertial unit provides outputs necessary for both navigation and automatic flight control without additional equipment. The small size of the INU is demonstrated in one unit that measures approximately 11 inches wide x 11 inches high x 19 inches long. These inertial platforms are providing accuracy with only 1.5 nm/hr error when tested over a four-hour period.

With such a guidance system there would be no waiting for gyros to get up to speed. Neither turbulence, high rates of turn, nor precession would consequentially degrade the system. Compared with mechanical gyros, the RLG offers the advantages of few moving parts and ruggedness, even under the high stress environment of missile flight. Size, weight and cost will be dramatically reduced as the design is perfected and the state of the art advances while, at the same time, superior accuracy will be attained. Foresight brings images of RLGs being used in your family car as standard equipment in ten years, continuously pointing out your position on a microfiche map. Who knows?

Although there probably always will be applications for platforms that provide rigidity of orientation, the Ring Laser Gyro is opening new alternatives in accuracy at reduced costs as that young workhorse, the laser, is harnessed in the field of navigation.

A graduate of the University of Virginia, Capt Boeck completed UNT at Mather AFB in 1971. He was then assigned to the KC-135 at Barksdale AFB, where he became an instructor navigator. Capt Boeck was reassigned to Mather AFB in 1977 and currently serves as a navigation systems instructor in UNT.



Stargazer

We are indebted to our friends at the Air Force Academy Planetarium for providing the material for this new feature. All you have to do is read the planet location and astonomical events information for your current month. We hope you find the information useful.

March 1979

SIGNIFICANT ASTRONOMICAL EVENTS

1. Full Moon: 13 March; New: 27 March.
2. Partial eclipse of the moon; visible in the northeastern portion of North America, 13 March.
3. The Vernal Equinox occurs at 0522 GMT on 21 March, beginning spring.

THE PLANETS

1. Mercury is at perehelion on the 4th, greatest eastern elongation (18°) on the 8th, stationary and greatest north latitude on the 14th, and inferior conjunction with the Earth on the 24th. It is visible until the 19th as an evening star low in the southwest after sunset. Mercury is located in Pisces the entire month, beginning retrograde on the 15th. After the 19th, it will be too close to the sun for observation.
2. Venus is at its descending node on the 18th. It passes through Capricornus this month and is a morning star.
3. Mars is at perehelion on the 18th. It passes through Aquarius this month, entering Pisces by the end of the month. It is now a morning star.
4. Jupiter, still in retrograde, becomes stationary on the 26th, after which time, it will move forward again. It is an evening star in Cancer.
5. Saturn, still in retrograde, reaches opposition on the 1st, after which it becomes an evening star until August. Saturn is in Leo.

April 1979

SIGNIFICANT ASTRONOMICAL EVENTS

1. Full Moon: 12 April; New: 26 April.
2. Lyrid Meteors: 22 April, 2100 GMT.
3. Mercury is occulted by the moon at 1300 GMT on the 24th.

THE PLANETS

1. Mercury is stationary on the 6th, at the descending node on the 7th, at aphelion on the 16th, and at its greatest western elongation (27°) on the 21st. Mercury is in conjunction with Mars on the 1st and is a morning star in Pisces.
2. Venus is at aphelion on the 22d. Venus is a morning star passing through Aquarius by the middle of the month and is well into Pisces by the month's end.
3. Mars is a morning star located in Pisces for the entire month. Mars is in conjunction with Mercury on the 1st.
4. Jupiter is an evening star in Cancer.
5. Saturn is an evening star located in Leo and still in retrograde.

May 1979

SIGNIFICANT ASTRONOMICAL EVENTS

1. Full Moon: 11 May; New: 25 May.
2. Eta-Aquarid Meteors: 2200 GMT, 5 May.

THE PLANETS

1. Mercury reaches its greatest southern latitude on the 7th, its ascending node on the

26th, superior conjunction with the Earth on the 29th, and perehelion on the 31st. Mercury is in conjunction with Mars on the 5th. It is a morning star until the 21st, after which it is too close to the sun to observe. It moves into Taurus near the month's end.

2. Venus reaches its greatest latitude south on the 14th. Venus is in conjunction with Mars on the 20th. It is a morning star, leaving Pisces by mid-month.
3. Mars is in conjunction with Mercury on the 5th and Venus on the 20th. It is a morning star exiting Pisces by mid-month.
4. Jupiter is an evening star in Cancer.
5. Saturn, still in retrograde, becomes stationary on the 10th, after which it begins moving forward again. It is an evening star in Leo.

June 1979

SIGNIFICANT ASTRONOMICAL EVENTS

1. Full Moon: 10 June; New: 24 June.
2. Summer solstice occurs at 2356 GMT on the 21st, beginning summer.

THE PLANETS

1. Mercury reaches its greatest northern latitude on the 10th. It is too close to the sun to observe until the 7th, after which it can be seen low in the west after sunset. Mercury passes from Taurus to Gemini and into Cancer by the month's end.
2. Venus is a morning star, entering Taurus by mid-month, where it will remain for the entire month.
3. Mars, a morning star, enters Taurus by the month's end.
4. Jupiter is an evening star located in Cancer.
5. Saturn is an evening star located in Leo.

Getting Hooked on Ground Missions

Captain William H. JACKSON
451 FTS/DO
Mather AFB, CA

In my three years on the KC-135 I've heard very few navigators complain about navigating in the "tank." Most navigators, however, have commented on the need for more or newer navigation aids at their station. But, overall we all look forward to the challenge of navigating a real aircraft on a "real" mission. However, when it comes to ground mission requirements it's another story. Comments such as "not again" or "how valid is this" are more than common, with the latter of the two heard from almost everyone. For, no matter how great the amount of time or degree of imagination put into it, or how realistic the ground mission,it's nearly impossible to get totally involved.

The mode of attack on the ground mission varies from navigator to navigator, but even the best find it hard not to take leave of their duties at the slightest distraction. They find it difficult to get totally into the swing of things. After all, if a problem arises they can look up the answer; they're not going to really get lost. They can set their own pace, realistic or not. I don't mean to give you the idea that ground missions are given short shrift. Most conscientious navigators will take their work seriously and will use this time to sharpen their skills and eliminate their errors. But, they'll be limited in the static ground mission because of rigid celestial shooting schedules and other parameters dictated by the particular ground missions. Often these constraints will conflict with the navigator's personal techniques. If the designers have used their imagination, ground missions can jog the nav's memories and make them think. But, still, something will be missing.

When your fellow crew members, the pilots, come back from their ground mission — the simulator, you note that they seem more concerned about their ordeal than you did about yours. To them it seems as though they have completed an authentic mission. They begin to go into detail about the equipment failures and related problems and what procedures they used to overcome their difficulties. They talk about how they followed this checklist or that procedure and how some new technique saved the day.

Up to a few months ago no operational unit in the Air Force had a ground mission simulator which required the nav to stay within given time constraints while allowing personal techniques. Imagine, a real time, visual, hands on ground mission, which would allow personal techniques and also aid in developing pacing.

The demanding project of developing such a simulator was taken on by Captain Greg A. Bose, of the 916th Air Refueling Squadron, Travis AFB. Captain Bose took an exceptional interest in celestial navigation, combined with his expertise in computers, and developed a product both pleasing to the eye and challenging to the user. Over two years, in his spare time, Captain Bose has been able to set up a workable, real time, computerized navigation simulator. With a visual display the navigator is kept abreast of all the necessary inputs for an accurate DR. It's not static, however, and the user must keep a constant watch on the instrument readings or suffer a bad DR. Falling behind the flight plan or getting too far off course can be corrected, just like a real mission, by changing airspeed or heading. It's probably after your first alter back to track that you get hooked; the hands on concept begins to take effect. You're no longer at the whim of a printed format, you're in charge. You begin to put extra effort into your log work, your DRs become more precise. You can beat this machine; you can get from A to B.

What about celestial bodies? When will the nav shoot? Captain Bose answered these questions with 54 stars, the moon, the sun and the planets. The program is set up so the navigator can shoot using any schedule and almost any celestial body. The simulator gives visual readouts for the HS at the times the navigator specifies.

With their own inputs and celestial techniques, navigators can try to beat the clock. That's right, a real time clock which uses the displayed information to keep a running position of where you actually are. This information can be assessed at any time you wish to stop the mission or check your position. Now you can find out if those new techniques will work with your favorite pacing schedule.

My first time, I used a program that took me from Travis AFB, California to Hickam AFB, Hawaii. Only wanting to spend an hour or two at most, I couldn't believe that after four and one-half hours I was still engrossed. Almost like the real thing! Well, at least I beat the machine and won't have to prove myself again. As I got up to leave, Captain Bose told me the simulator was programmed with nine levels of difficulty, and I had chosen one of the easiest. My response was, "When can I try it again?"

A graduate of Bridgewater State College in Massachusetts, Capt Jackson was commissioned through OTS. After UNT in 1975, he was assigned to the KC-135 at Travis AFB for three years and served as an instructor navigator. At present, Capt Jackson is a UNT instructor with the 451 FTS, Mather AFB.

TIME

Captain Craig D. VOSS
70 AREFS
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Time is money and nowhere is time more important than in today's air navigation. An unreliable watch can mean the difference between mission accomplishment and an abortive rendezvous. Flying a mission would be impossible without an accurate timepiece. Perhaps too many of us take time for granted.

The National Bureau of Standards is responsible for keeping our watches as accurate as possible. The Time and Frequency Division of the Bureau conducts many projects and research including keeping half the world on time with a costly atomic timepiece. That device is accurate to .503 seconds within a year.

The atomic device is kept in Boulder, Colorado, and broadcasts over radio stations WWV of Fort Collins and WWVH of Kauai, Hawaiian Islands. Clock time is based on the earth revolving on its axis and around the sun. The problem lies in the fact that the earth's rate of rotation is erratic which, in turn, throws our atomic clock off by as much as 30 milliseconds. Not enough to make you late for the morning briefing, but enough that over 600,000,000 years ago our day was only 21 hours long. Thus our earth is rotating slower every year.

To the navigator, the value of time is ever important. Medieval astronomers and navigators discovered long ago that accurate latitude readings could be observed by measuring the altitude of the pole star, the sun, or any star when it crossed the meridian. The greatest problem remained how to determine an accurate longitude at sea. In 1522, when Juan Sebastian De Cano completed the circumnavigation begun by Magellan, he thought it was Sunday and wondered why church bells ashore weren't ringing. He overlooked the fact that he had gained a day on the sun.

In the early 18th century, due largely to a number of maritime accidents, the British government offered 20,000 pounds sterling to the first seaman who could discover a method of determining longitude within 30 miles after a voyage of six weeks. When John Harrison finally invented an accurate watch and a method of taking time observations of heavenly bodies at sea, the grateful British government gave him 20,000 pounds. (The forerunner of today's Giant Voice Competition.) By the end of the 19th century, inventors had created a clock accurate to within one hundredth of a second a day. By then, the mighty railroads had spanned the continental US, yet each town had kept local time based on noon time sun. There were some 300 different local times in the US alone. Needless to say, the train schedule was as predictable as next month's weather. The country soon was divided into four time zones, 15 degrees of longitude each, representing one hour of sun travel. Daylight savings time came about in World War I to save fuel and has been with us ever since. Within recent years, great advances have been made in electronic aids to navigation including VOR, radar, Loran, INS, digital watches and navigation computers. The next step for navigation watches, which haven't changed much in 50 years, might be a table model digital stopwatch with normal tolerance of +15 seconds a month. Better yet, incorporate a digital readout multifunction chronometer combining full stopwatch features with the new digital navigation calculators.

Yes, this type of time does cost more money but so do lost rendezvous, off-target air drops and unreliable navigation due to inaccurate and antiquated timepieces.

Editor's Note: A prototype hydrogen maser time reference for NAVSTAR has demonstrated accuracy to within one or two seconds over thirty million years. Soon, they'll be no excuse at all for missing that morning briefing!

Capt Voss graduated from the University of Kentucky in 1973. After completing UNT he was assigned to the AC-130 at Korat AB, Thailand. In 1976, he was the 305th Air Refueling Wing representative in the Giant Voice Competition. Capt Voss now is in Instructor Upgrade in the KC/EC-135 at the 305th Air Refueling Wing, Grissom AFB.

BOMBER NAVIGATION

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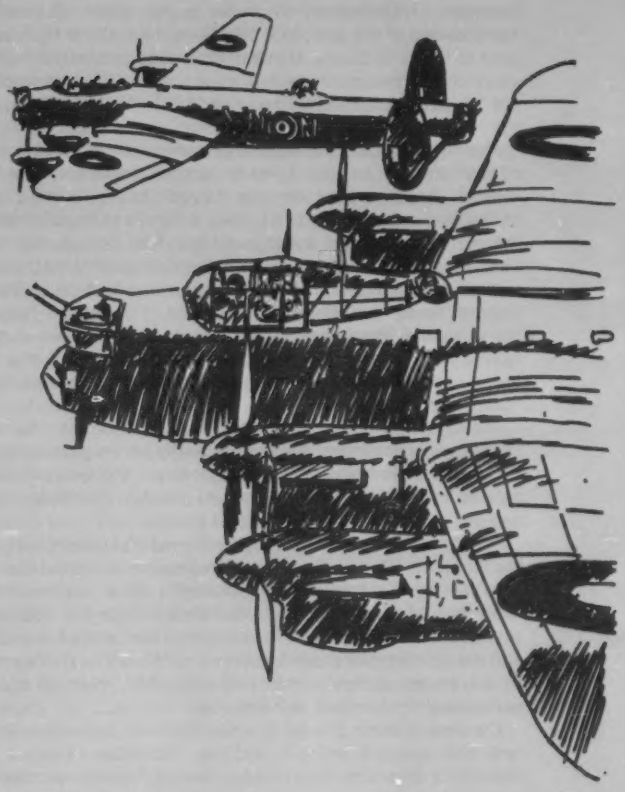
Editor's Note: This is the second half of the story started in our last edition. We are grateful to the author and our compatriots at Polaris for their permission to reprint this important lesson of the role of navigation in the use of air power.



British bombs, put into the right place, could do a great deal of damage. The trouble was that they were simply not being dropped where they would hurt. Lindemann, when he put forward his proposal, actually bit the sour apple — he admitted that the Bomber Command policy of precision bombing was useless because navigation was so poor, and he sought a policy that would choose targets Bomber Command had some chance of hitting. This was, indeed, the first realism that had permeated bombing planning since 1939. Furthermore, it must be stressed that in early 1942, when Russia was calling for help, Britain had no way to hit back at Germany proper except to employ the bombing offensive. It was very nearly bombing or nothing. With Churchill at the helm, it could never have been nothing.

Lindemann's chief mistake was that he did not downgrade bomber navigation enough. He estimated that half the bombs would fall in built-up areas, whereas Blackett would not go higher than a quarter. Actually, only about an eighth did, at least during the rest of 1942. But to someone who had been hearing about feats of precision bombing, proudly described by senior officers and repeated in the press, Lindemann's estimate was an extreme case of independent thinking.

Thus, the new policy was formulated to overcome defects in navigation; the objections to strategic bombing revolved around navigation, and the fact that it did not work again must be chalked up to navigation. Lindemann based his plan on hitting cities; Bomber Command, for at least another year, could not even consistently hit the cities.

Meanwhile, of course, scientists and engineers were working feverishly to provide the tools for accurate navigation, and RAF planners were working out methods of making the best use of them, and of improving their tactics to overcome the fatal effects of navigation inaccuracy.

The first, and easiest, action was to change the composition of the crews. Bomber Command had started the war with its planes manned by two pilots, an observer (a navigator bomb aimer), a wireless operator, and one or two gunners. Before long, the number of pilots was cut to one. The duties of the observer included navigating the plane to the target and back, dropping the bombs, and sometimes firing a gun. Making the transition from navigating to dropping the bombs was, however, too difficult, particularly since it required night-adaption of the observer's eyes. The solution was to employ a specialist bomb-aimer (who could not be called a "bombardier," since this term denoted an artillery rank corresponding to corporal). These "air bombers," as they were officially called, acted as copilots during takeoffs and landings, but their chief task was that of assistant navigator, a function later accomplished mostly by operating the radar. They also took sextant sights and obtained drift checks by using the bombsight.

Tactics were also changed drastically. For the first three years of the war, crews were allowed to reach and attack their targets anyway they wished, and usually were allowed to choose their own routes. This was abandoned for "bomber stream" tactics, in which the aircraft were carefully briefed to stay close to a specific track and to make good specified timing points. A good part of the objective, in thus concentrating the fleet en route and at the target, was to saturate the defenses, as well as to allow an elaborate campaign of spoof raids and doglegged approaches designed to mislead the enemy as to the selected target. Concentrating the raid was also designed to overload the enemy fire-fighting and civil defense organizations.

Another highly important change was to form the Pathfinder Force, under the command of Air Vice Marshal D. C. T. Bennett, an irascible Australian who was the "complete airman"—he was a qualified pilot, air gunner, bomb aimer, flight engineer, and wireless operator, and he had written a book on navigation. The Force was composed of elite crews, initially selected personally by Bennett from the most successful and experienced men in Bomber Command, who were given special training and provided with the most advanced navigational aids. The function of the Force was to mark the targets for the main force crews to bomb.

Nevertheless, in 1942, Pathfinder Force started its career by marking Harburg instead of Hamburg (some ten miles away), missing Flensburg completely, and failing to find Saarbrucken. On 10 December 1942, Bennett sent out one of his crack crews, captained by Squadron Leader S. P. Daniels, to mark Frankfurt, a city of half a million people located on a distinctive river, after which Daniels was to inaugurate a new technique by acting as "Master Bomber." The weather was bad, however, and after the

raid the Police President of Frankfurt reported that "although the sirens sounded that night, not a single bomb fell within the city boundaries." Darmstadt, 17 miles to the south, received its heaviest raid of the year; four people were killed. Far from being able to locate factories, Bomber Command proved, after three years of war, that in this raid its most highly skilled crews could not be relied upon even to find a specific city, and that if they did, their raids could be virtually harmless.

Aside from finding the right target, one of the main objectives of the Pathfinder technique was to concentrate the bombing. The original tactics called for the targets to be marked with incendiaries, dropped in two passes to form a cross, after which the main force would bomb the fires. The incendiaries were always scattered, however, and the Germans countered them by setting dummy fires. The British answer was to drop brilliantly colored flares that Bennett christened "Paramatta" (ground markers) and "Wanganui" (sky markers, to be bombed as they floated down by parachute over cloud-obscured targets) after two towns in his Australian homeland. The Germans called them "Christmas trees."

The Germans tried to imitate the flares also, but by ringing in changes on color codes, the British usually were able to outguess them. In the Normandy campaign, however, the Germans used colored smoke from artillery shells to simulate Pathfinder flares and brought bombs down on Allied troops.

The Pathfinder crews were highly trained and determined, but the Frankfurt affair and similar embarrassments proved that the best navigators in the world cannot reach precise targets without sophisticated navigational aids. British scientists and engineers set about developing them. They began to be installed in aircraft and the co-operating ground stations in 1942, although they were by no means common until well into 1943, even in aircraft performing the function of Pathfinder.

The first of these, the Air Position Indicator, was designed to help the navigator with his plotting. Previously, most of the navigator's time was taken up by drawing lines on his chart to represent the aircraft's path through the air. To do this, the pilot had to be relied upon to maintain predictable airspeeds and headings, tell the navigator whenever he was about to alter heading, and fly straight and level most of the time. If he began to maneuver without telling the navigator what he was doing (as he would have to do if he were attacked by a fighter, or forced to dodge flak bursts), the navigator would be unable to keep track of the aircraft, simply because he could not work fast enough to do a "real time" job. In addition, the navigator was unable to plot curved lines, and had to approximate the aircraft's path by means of straight segments. Furthermore, working under the greatest tension, the navigator was extremely vulnerable to mistakes.

Automating what had been the navigator's most onerous job regained for the pilot his ability to maneuver freely without immediately throwing the dead reckoning position into grave doubt. In other words, it gave him "tactical freedom." The navigator could now devote most of his attention to fixing his position and finding the wind, which was always his greatest worry and absorbed most of his ingenuity. Squadrons equipped with APIs immediately exhibited greatly improved navigation.

The next task was to give the navigator something with which to fix his position. The two most successful devices for general use in the bomber fleet generally were Gee and H2S. Gee was a ground-based aid, working on the same principle as Loran, which provides hyperbolic lines of position by comparing the time of receipt of two pulses received from two ground stations. These position-lines, plotted on an airborne map, allowed the navigator to fix his position to under a mile. Gee (still in use in Europe) allowed Bomber Command to make some spectacular attacks, but the Germans quickly devised means to jam the Gee beacons, which were located in Britain, with the result that, by 1943, the navigator found the trace-presentations of his "Gee box" a solid fence of unintelligible "railings" by the time he reached the French coast. With Gee alone, the navigator could get a good start for his trip, but over France and Germany, he was back where he had been in 1941. Indeed, the chief en route means of navigation taught Bomber Command crews in 1943 was to take bearings on flak bursts directed at other aircraft, estimate the city from which they came by means of the dead reckoning plot, and calculate a "Most Probable Position," which was hopefully within 10 or 15 miles of the aircraft's actual position.

To queries from student navigators, as to how sure they could be that these flak bursts would be around for observation, the answer was, "There'll be some poor devil off track over the big towns along your route — you can depend on that."

The other aid was H2S — airborne search radar, giving the map-like Plan Position Indicator view of the area over which the aircraft was flying, with built-up areas and coastlines (and sometimes lakes) showing up on it. Since this was in the infancy of radar, serviceability was only fair, definition was poor, range was limited to about 20 miles, (or 40 if a good target such as Heligoland was available) interference from other aircraft was a nuisance, and the techniques required for accurate radar-return interpretation (later brought to perfection by the US Air Force) had not yet been developed. Nevertheless, fixes from an unjammable device were now available, and though it was by no means impossible to misidentify towns or coastlines, accuracy to about a mile or two was achieved — town-accuracy, not factory-accuracy.

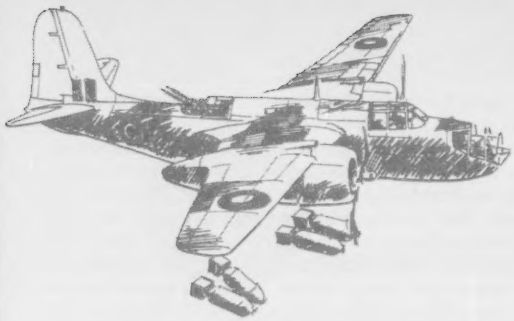
Supplying these aids was a magnificent technical feat, especially since they were conceived, developed, debugged, and put into production within a period of about two years. To perform a comparable task today takes seven years.

The Pathfinders received the equipment first. Using it, they marked the targets, and under the eyes of a "Master Bomber," a highly experienced veteran who acted as master of ceremonies for the raid, they replaced the flares as they burned out, corrected badly placed flares, cancelled German dummy targets by specially colored flares, and changed the aiming-point if the Master Bomber so decided.

It was still by no means precision bombing, however, since the average marker fell 0.7 of a mile from the aiming point, and the actual bombs fell farther away than that, largely because of the tendency of raids to creep back as the attack progressed. The bomber crews were under a strong temptation to drop on the first fires they saw, since the rest of the crew exhorted the bomber-aimer to "Pull that bloody plug and let's get out of here!" Against Berlin, the creep-back stretched for 30 miles. In short, it was a precise kind of area bombing. Bomber Command by 1943 could count on hitting the right town; its navigators were becoming better trained and its aircraft better equipped. Still, the technique was imperfect and remained so as late as February 1945 when Chemnitz was attacked.

There were two schools of thought among the Pathfinders themselves. Bennett favored high-altitude flare-dropping using radar, while Air Vice Marshal The Honorable Ralph Cochrane, the head of No. 5 Group of Bomber Command, which had its own Pathfinders, favored finding the target with radar and dropping flares on it from Lancasters, and then having a high-speed Mosquito duck down to a few hundred feet to drop the actual markers.

The new techniques took time, however, and Lindemann's 15 months passed without achieving even one-tenth of what he predicted. German production showed no reduction; German morale was steadfast. Then, on 29-30 May 1943, the new



equipment, tactics, training and skill all came together in an attack on Wuppertal, a city in the Ruhr.

For the first time the crews were actually briefed to attack built-up areas instead of the industrial targets which Bomber Command had always previously gone through the motions of designating as targets. Seven hundred and nineteen bombers were dispatched to cross the city on a heading of 068 degrees, where any bombs prematurely dropped would still hit the city. The first markers were red flares dropped by means of the radar aid "Oboe" controlled from the ground in England, and the first bombers dropped incendiaries that started brilliant fires. It was the best raid Bomber Command had ever launched, but even at that, only 475 of the crews dropped their loads within three miles of the aiming-point; 40% of the aircraft still scattered their bombs more or less at random. Despite this, the attack set back Wuppertal-Barmen's production for 52 days and killed 2,450 people for 1,900 tons of bombs dropped, including incendiaries. This was some six times what Blackett had predicted. One hundred and eighteen thousand were made homeless; Lindemann's estimate would have set a lower limit of 190,000, using his yardstick of "100-200" homeless per ton of bombs dropped.

A little less than two months later, Bomber Command launched a four-raid attack on Hamburg. In addition to their new skill at navigating, the bomber crews were using "Window" (Chaff) to jam the German gun-laying radars. Since Hamburg is located on a conspicuous estuary, with Heligoland acting as a prominent radar signpost to tell the Pathfinder aircraft where to turn, the bombing concentration was excellent.

The bombers achieved a macabre bonus. During the second raid, in which 969 tons of incendiaries were dropped, the fire services were overwhelmed, and 40 minutes after the first bomb fell, the first fire storm which Germany suffered was in progress.

When the four raids were over (the fourth was launched in poor weather, and had little effect), more than 43,000 people were dead (30 times Blackett's estimate) and 753,000 were homeless (Lindemann's bottom limit was about 800,000). Of 524 major factories, 163 were destroyed, and 4,118 of 9,068 smaller ones. In the harbor, 180,000 tons of shipping were destroyed.

Two months later, it was Kassel's turn. On 22-23 October, the center of German tank and locomotive production received 1,824 tons of bombs from 444 bombers, of which 380 (85%) put their load within three miles of the aiming point. A fire storm developed and destroyed 27,000 homes, killed 5,800 people (Blackett's estimate was 360), and made 150,000 people homeless (Lindemann's lower limit was 180,000). The entire gas, electricity, and water system was put out of action, and the entire city's production paralyzed. Some 70% of the casualties were asphyxiated or burned to death. Nobody in Britain had anticipated this; it accounted in large measure for the inaccuracy of Blackett's predictions in the murderous raids which began in 1943 and lasted until the war's end.

In 1944, the area attack on Germany slackened, partly because bomber activity was concentrated for most of the year to bombing railway targets (largely in France) in preparation for D-Day, and after D-Day in supporting the ground troops, but it did not cease. German defenses were making it expensive, however; on the night of 30-31 March 1944, 95 of the 795 bombers that attacked Nuremberg did not return.

A new Pathfinding technique was used against Munich on 24-25 April 1944, when 260 Lancasters belonging to Sir Ralph Cochrane's No. 5 Group dropped 1,100 tons of bombs, 90% of which were in the target area. Despite Air Vice Marshal Bennett's insistence that low-level map-reading was impossible, No. 5 Group's aircraft, crewed by such super-experts as Group Captain Leonard Cheshire, VC, DSO, DFC, repeated the exercise on 12 September against Stuttgart, wiping out the center of the city. A technique of briefing three streams of bombers to use the same markers, delaying the dropping of their bombs for a specified number of seconds, thus obtaining the effect of three aiming-points for the price of one, was tried out against Konigsberg on 30 August. On 11 September, Darmstadt was smashed, with 12,300 dead (against Blackett's estimate of 175).

The whole process culminated during 13 to 15 February 1945, when an RAF double-blow at Dresden (two raids three hours apart) followed by a USAAF raid, killed 135,000 people, made 400,000 homeless, and devastated 16 square miles (as compared with the six square miles of London smashed during the whole war). The raid was a bombing and navigational tour de force; spoof raids at four other cities drew off German fighters, Lancasters dropped flares on radar to light the target, Mosquitoes dashed across the city at low level to drop the red target markers by the light of the Lancaster's flares, and the Master Bomber kept the target markers replaced and controlled the raid. The effect was murderous. More people died than were killed at Hiroshima.

When Bomber Command tried to follow the Dresden raid with an attack on Chemnitz, however, the target was covered by clouds which kept the Pathfinder markers from remaining visible long enough to allow accurate bombing, the crude radar of the day failed to distinguish the target with any certainty, and the raid was a comparative failure. The deficiencies of airborne radar were also demonstrated by the fact that 40 B-17s, briefed to attack Dresden that day, missed the city completely although they were equipped with APS-15 radar, and bombed Prague instead.

This incident illustrates that the Americans suffered from the same difficulties as did Bomber Command. When the B-17s and B-24s first went to England, their commanders were committed to a policy of daylight bombing, using the famous Norden "pickle-barrel" sight. The USAAF bombers received two rude shocks in a row, however. First, their navigation, learned in the clear air of Texas, proved even weaker than that of Bomber Command when the Fortresses began to fly over smoky, cloud-covered Germany. Next, they found that German fighters were able to inflict crippling losses on unescorted bombers, despite the fact that the B-17s carried, in the words of a rude RAF song "Ten tons of ammo and one teeny bomb." It was the development of the Mustang and Thunderbolt long-range fighters that made the daylight offensive workable.

Adherence to the classical tenet of air warfare, obtaining air superiority, allowed daylight bombing to be carried out without prohibitive losses. Nevertheless, the USAAF generals greatly overestimated their crews' navigational ability, and underestimated the navigational task. Furthermore, although their targets were ostensibly precision objectives, at Hamburg, Dresden, and many other cities, the USAAF joined in the area-bombing attack.

By the end of the war, the aircraft of Bomber Command and the USAAF had some solidly barbaric achievements to their credit. They had proved they could wipe out cities, if the weather was

clear enough over the target to allow accurate marking, if the weather was good enough en route to allow attacking aircraft to maintain their tracks and their timing, and if enemy opposition was light enough not to force the bombers to jettison their loads prematurely. The task was still so difficult, however, that Bomber Command and the Eighth Air Force were never able to put attacks on two cities back-to-back, one following the other closely enough to create a crippling, cumulative drain on German war production and morale.

Despite their success, the task was so difficult that the Strategic Bombing Commission concluded after the war that the strategic bombing offensive had been a failure. On balance, the attacks had cost the Allies more in men and planes and money than it cost the Germans in war potential. In fact, German war production reached an all-time peak in September 1944. The really effective part of the bombing was not the attack on cities, but on German transportation and oil supplies.

There is no doubt that it would have been far better during 1942 to have devoted the lion's share of airborne effort to patrolling the seas against submarines, to providing extensive support for the Army in Africa and Italy, and mounting more of the special attacks such as the one that breached the Mohn and Eder dams. The attack on German morale never succeeded, since the German will to fight never cracked until the Allied armies met on the Elbe. In many ways, despite sporadic successes, the strategic bombing campaign is almost an object lesson in how not to fight a war.

But the big bombers came a lot closer to their objective than it has been fashionable lately to admit. After Hamburg, Alfred Speer, Germany's economics minister, told Hitler that six similar raids close together would leave him unable to maintain arms production. Bomber Command did not, however, have the means to mount the raids.

There actually were sufficient aircraft if they had been able to place their bombs close enough to the targets. What made the task impossible was the same thing that had made the first three years of the campaign a hopeless failure — lack of navigational ability, largely owing to their lack of sophisticated equipment, particularly electronic navigation aids. When successes came at last, they were the result of actually finding the correct target, unquestionably a navigational task; of concentrating the actual bombing, a task shared between the navigator and the bomb-aimer; concentrating the bombing in time (at the end of the war, a whole attack could be completed in ten minutes), the task of the navigators; and keeping on track out and home, which saturated the defenses and allowed aircraft to survive to drop their bombs or to bomb another day, again the job of the navigation team.

The area campaign itself, ironically, was "justified" because of the German area attacks on cities such as Coventry, which were in turn "justified" by the Germans on the grounds that the Allies had on 10 May 1940 bombed Freiburg, killing 57 civilians including 22 children. The attack had in fact been made on Freiburg by German Heinkels, because of a navigational error.

The navigational state-of-the-art led the strategic planners along a path of miscalculations, each of which unhappily involved a belief in one's own propaganda. When German fighters made it impossible to operate bombers by day, the Royal Air Force convinced itself that night bombing was as accurate as day bombing, mostly because of mistaken faith in optimistic crew reports, but largely because night bombing was all they could do. After clinging to this belief for two-and-a-half years, a conversion to area bombing was forced on them, once again because the bombers could do nothing else. The War Cabinet convinced itself that area bombing would, in fact, be effective; that it would break German morale and cripple German production. The planners also had to force themselves to believe that the bombs could hit the cities, which for 15 months they could not. In the last year of the war, moreover, when navigation aids and better techniques allowed precision bombing to be carried out even at night against such targets as marshaling yards, factories, and dockyards, so wedded were they to the area-bombing concept that they continued to stir up the rubble of Essen and Hamburg rather than go after the now-reachable factories. When, in 1944, the German armies in France were being crippled by their smashed railway system, bombers were only grudgingly allotted to pounding the transport system, which later proved to have been decisive; instead, they were sent against German cities at every opportunity.

Either better navigation, or better knowledge of how bad the actual navigation was, would have kept the planners on the right track. If the bombers could have navigated to a quarter of a mile or so, they need not have been launched at cities. Having been launched at cities, if they had been able consistently to find them despite bad weather and darkness, and if the bombs had fallen within a mile or two of their targets, it is quite conceivable that they might have destroyed enough of the cities to break either the German will or power to fight. If the fact that the new Pathfinder Force could not even be sure of finding the right town had been recognized in 1942, the aircraft needed by Coastal Command could have been provided, thus hastening the pre-invasion build-up. If the pitiful lack of success at night had been evident after 1940, the British could have made daylight bombing possible again. After all, the Mustang was built to a British specification and powered with a British engine. There are many "ifs" here, but all of them revolve around navigation.

Some of the lessons have been taken to heart. Two concurrent ones — the fact that navigational accuracy is crucial to a bombing mission's success, and that the best-skilled human being in the world is helpless to achieve it without sophisticated aids — have been recognized by an outpouring of money and effort to develop a series of intricate navigational devices, including digital computers, automatic sextants, Doppler radar, Hiran, Shiran, and many other variants of the original Oboe, and inertial navigation systems, which have been installed in military aircraft.

Navigation training has been greatly improved. Immense efforts have been devoted to improving the navigators' maps. The emphasis on accurate bomb-aiming has been kept at concert pitch for 20 years.

The results have been apparent in recent reports of B-52 bombers dropping bombs within a few hundred yards of Marine positions at Khe Sanh, despite cloud cover, by the skillful use of radar, ground beacons and reflectors, and airborne computers, plus highly skilled men to use them.

Other lessons can be learned. One is that courage and determination — 50,000 of Bomber Command's 100,000 men lost their lives — are no substitute for technical excellence. A continuous effort to improve capability and techniques is always needed, and parallel equipment and methods often prove themselves and sometimes save the situation. Those who receive criticism when they strive to improve military equipment which already seems good enough should remember that in 1939 the RAF's marshals were convinced they could win the war all by themselves, and that the equipment they had at the time was good enough.

The final lesson, that facts should always be looked in the face without being clouded by preconceived ideas, is probably as hard to learn as it ever was.

Nevertheless, it is still true, as historian Edward Gibbon said, that "the winds and waves are on the side of the ablest navigators," and this applies also to the winds aloft.

NAVIGRAMS

NAVIGATOR MANAGEMENT STUDY - PHASE II: In June 1978, an AF/MP directed study confirmed a continuing requirement for approximately 9,000 Air Force navigators during the next 10 years (current requirement is 10,800). A second study, undertaken in August, examined navigator utilization and has developed recommendations for managing navigators during the corresponding period. The resultant initiatives are being staffed and will be presented to AF/CC for approval. Follow-on publicity will be released to AF related news media and printed in this magazine.

COMPLETE THE FOLLOWING:

(a) Briefly describe early Egyptian civilization.
(b) For what were the following noted: Lycurgus; Solon; Hasdrubal; Xerxes; Socrates?
(c) Tell of the founding of Constantinople.
(d) Discuss briefly the causes of the Boer War.
(e) Make a list of the principal English authors of the nineteenth century and name one work of each.

These questions were taken from a 1927 examination to qualify for appointment as Flying Cadets, US Army Air Corps.

THE TURBOCLAIR PROCESS: Orly and Charles de Gaulle airports use a thermo-kinetic fog-dispersal process to raise conditions as bad as ceiling/visibility of zero/150m to at least 50m/600m. The exhaust from 13 (14 at Orly) buried and remotely controlled jet engines is aimed by a system of swivel gratings to achieve best results commensurate with wind and fog conditions. The hot gases diffusing above the runway raise ambient temperature a few degrees--enough to vaporize the suspended water droplets we call fog.

IN A FUTURE ISSUE we hope to include the remarkable story of the adventures of Lt Col Delmar R. Mineard, recently retired from active duty at Castle AFB. The flavor of his story is captured in this excerpt: "My luck stuck with me through the rest of this combat tour until my last mission to Berlin. We took a direct hit and I recall that same Mack truck hitting me. This time I was being shoved out through the plexiglas nose of the aircraft. I had on the harness for the chest type parachute plus a flak helmet. The parachute was laying by my right foot on the floor. I remember ducking my head down as the plexiglas came at my face; then complete terror as I felt the blast of wind on my body as I went right through the hole. I can only think that by reflex action or some guiding star, I was able to grab the chute as I went out and snapped it on while I fell."

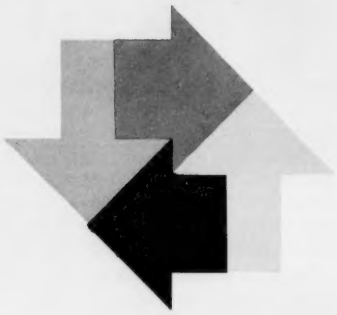
THE ATC COMMANDER'S TROPHY is presented to the most outstanding graduate of each UNT class. The winners for the first third of FY 79 were:

RANK/NAME	CLASS	HOMETOWN	ACFT	SQUADRON/BASE
2d Lt Frederick L. Breitinger, Jr.	79-01	San Bernardino, CA	F-111	27 TFW/Cannon AFB
Capt David R. Chesser	79-02	Greensburg, PA	FB-111	4007 CCTS/Plattsburgh AFB
2d Lt Bruce W. Hendricks	79-03	Gastonia, NC	F-111	20 TFW/Upper Heyford, England
2d Lt Keith W. Kurtz	79-04	Stewartstown, PA	F-111	366 TFW/Mt Home AFB
2d Lt Mario A. Garza	79-05	Alice, TX	B-52	NBT; 596 BMS/Barksdale AFB
2d Lt Paul J. Avella	79-06	Smithfield, RI	F-111	27 TFW/Cannon AFB
2d Lt Douglas L. Schrag	79-07	Colorado Springs, CO	B-52	NBT; 69 BMS/Loring AFB

STARLIFTERS GET NAVIGATION SYSTEM: MAC has completed a $69.6 million project to install dual inertial navigation systems aboard its C-141s. As a result, the command's force of C-141 navigators will be reduced by about half, although the final strength has not been determined. According to MAC personnel officials, the reduction in the navigator force will be a planned reduction and should be completed in fiscal year 1983. General William G. Moore Jr., MAC Commander in Chief, announced the reduction decision 16 Nov 78 after he reviewed results of a program which tested the realignment of aircrew member duties to accommodate the operation of the new inertial navigation systems. The general, according to a command report, decided to use the current crew complement without a navigator for airland operations and to retain the navigator for airdrop operations.

LOST Again

Major William E. BLUE



On a flight from Clark AB to Diego Garcia our navigator who was lost and found 1 Jan 78 is again in trouble. He missed his destination due to a time error of one hour on his pre-comps. While trying to figure out where he is, the worst happens, they run out of fuel. An island is located on the radar and the aircraft is directed to a crash landing site on the beach at the south end of the island. A good crash landing is made and all on board are safe, except for the navigator who is taking a terrible verbal beating from the crew. As navigator he must determine where they are. He has all of his navigation equipment and takes instantaneous shots, but this time he uses the correct time. He records the following three bodies and plots his position.

GMT (11 Jun 79)	HO	BODY
1710	24°34.8′	Moon
1714	28°19.6′	Acrux
1718	27°04.6′	Alioth

The next morning the crew determines that no one is around the island, so they decide to take the life raft and try to drift over to another island. After about 30 hours in the water they arrive on a point of land at the north end of the second island. Getting out of the raft, the navigator drops his sextant. He then takes three shots on the sun with the following results.

GMT (13 Jun 79)	HO	BODY
0620	50°22.0′	Sun
0820	62°31.8′	Sun
1020	49°19.6′	Sun

Dissatisfied with the results of the 0620 and 0820 shots, he recalibrated the sextant before the 1020 observation. As a result of the navigator's excellent work, our crew is later picked up by an HC-130 at the east end of the island. While walking to the end of the runway to board their rescue aircraft, the crew takes a vote — and decides to let the navigator join them anyway.

Name the two islands and the coordinates of our crew's locations.

Name	Latitude	Longitude
Island 1	_____	_____
Island 2	_____	_____

Mail your answer to:

Editor, THE NAVIGATOR Magazine
323 FTW/DOTN
Mather AFB CA 95655

On 15 May 1979, three names will be drawn from the lot of correct answers. The three winners will each receive a blue naugahyde DR kit holder.

Editor's Note: The DR kits were furnished by the author, Major William E. Blue. Major Blue has recently gone PCS to the 92d Bomb Wing, Fairchild AFB after having been the Chief, Wing Navigation Branch, 305th Air Refueling Wing, Grissom AFB. Major Blue is a long-time contributor to THE NAVIGATOR.

(Continued from page 3)

student comes up with his own idea (as if he were the first) on a quicker method. And on the "Quicker Method" more steps are necessary, thereby inducing more possible human error for an erroneous end result anyway.

But with all the new systems that modern technology has introduced into navigation today it's no wonder that perhaps even some of us have forgotten it is still the professional navigator (THE MAN) who will, in the end, complete the assigned mission during emergency situations. And if "THE MAN," from today forward, isn't trained and his proficiency isn't maintained in the "old ways" of navigating, I, for one, sincerely hope we never have to go into another war.

Edward T. Hunt
MGYSgt, USMC
VMGR-252, 2d MAW
MCAS Cherry Point, NC

Dear Editor

I thank Sgt Hunt for the compliment, but I think he misread me a little by implying that I don't like new ideas. I think that new techniques are one of the main purposes of this magazine. In fact, the very existence of THE NAVIGATOR proves the creative nature of our profession. Nor do I believe that nav school teaches the easiest, fastest, best, or most accurate way of doing things. They teach the basics, which is as it should be. You have to learn to walk before you run. Finally, I don't want Captain Campbell to be overly criticized on this. I differed from him on a couple of technical points and I thought his procedure was a bit complicated, but his main point about the importance of the selection of the assumed position is valid. Above all, he is a contributor, and he made us think, and I personally got something out of the whole deal.

Gary C. Eickmeier
Captain, USAF
2 BMW Navigation Officer
Barksdale AFB LA

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